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OVERSIGHT OF THE NATIONAL SCIENCE FOUNDATION

HEARINGS

BEFORE THE

SUBCOMMITTEE ON
SCIENCE, RESEARCH AND TECHNOLOGY

OF THE

COMMITTEE ON
SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

ONE HUNDRED FIRST CONGRESS

FIRST SESSION

MARCH 9, 14, 16, 1989

[No. 21]

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[*] Ranking Republican Member.

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OVERSIGHT OF THE NATIONAL SCIENCE FOUNDATION

THURSDAY, MARCH 9, 1989

U.S. House of Representatives,
Committee on Science, Space, and Technology,
Subcommittee on Science, Research and Technology,
Washington, DC.

The subcommittee met at 9:45 a.m., in room 2318, Rayburn House Office Building, Hon. Doug Walgren, chairman of the subcommittee, presiding.

Present: Representatives Walgren, Brown, Boehlert, Slaughter, Campbell, Schneider, Henry, Johnston, Skaggs, Nagle, and Morella.

Mr. Brown [presiding]. The subcommittee will come to order.

The Chairman has been temporarily detained, and I have been asked to start the meeting, which I am more than happy to do, and the Chairman has an opening statement which I will wait until he gets here for him to deliver in his own inimitable style, and then I will recognize our Ranking Republican Member, Mr. Boehlert, for his opening statement.

Mr. Boehlert. Thank you, Mr. Chairman.

Of all the topics we will discuss this year, none is as important, none is of greater concern to the general public than the one in which we will engage this morning, and for good reason.

Our public school system functions like the canary in the coal mine, alerting us to grave dangers that threaten our economy and our society.

We have convened this morning to diagnose and develop cures for one very sick canary. The sources of that illness are numerous, but I believe that more than anything else the canary has been choking from the atrophying of America's teaching profession. The future success or failure of America's schools will be determined in large part by the quality of their teachers.

After all, when each of us looks back on our own schooling, we realize it is the outstanding teachers that made the difference, not outstanding textbooks or lab equipment or computers. Good teachers have a chance of triumphing over even the worst conditions. Bad teachers can fail even in the kindest, gentlest environment.

But where are the teachers of the future?

We can no longer depend on a once reliable source, women who had no other opportunities open to them.

The statistics paint a dire picture. Students declaring an interest in teaching are among the lowest scorers on SAT exams. Schools are finding it difficult to fill math and science teaching positions.

Increasingly, high school math and science courses are taught by teachers with little or no training in these fields, and the situation is worse at the elementary level.

In New York City, for example, one in every three science teachers is teaching without a specialized license. People used to joke that those who can't do teach, but we are in real trouble when those who can't teach teach or, still worse, when those who can't learn teach.

Yesterday I introduced a bill to attract more top students into this critical profession. The bill would offer federal scholarships of $7,500 to college juniors and seniors majoring in science, math or engineering if they agreed to teach two years for each year they received the aid.

This is the type of action we need if we are to reverse the steady deterioration of our schools. We have sat back too long as the evidence of a crisis has mounted.

It seems at times that we almost took a perverse pleasure in the issuance of each new report documenting our demise, reveling in its familiarity. We have spent too much time, in the words of one critic, "amusing ourselves to death."

Rather than being daunted by the overwhelming nature of our task, we need to be inspired by the optimism and idealism of another time of educational challenge.

John Kennedy's words should propel us. "All this will not be finished in the first 100 days, nor will it be finished in the first 1,000 days, but let us begin."

Our distinguished witnesses today, especially the teachers, will help us decide how to make that beginning, but we must act.

Mr. Chairman, Thomas Jefferson once wrote that the problem of slavery awakened him like a fire bell in the night.

Well, education is the central question of our day just as slavery was in Jefferson's, the issue that will determine the future structure of our society and the health of our economy.

Too many Americans decided to sleep through the alarm that Jefferson heard so crisply, and we are still paying the price.

If we fail to respond to the growing alarm about our public schools, the effect will be equally devastating.

I want to thank you, Mr. Chairman, and I also would like to explain that because of my deep personal interest in the matter before us today I would like to spend every single second of every minute of every hour in this hearing, but shortly another committee upon which I serve will be coming to grips with crisis legislation dealing with the Eastern Airlines strike, and so I will have to excuse myself shortly, but I will be back as often and for as long as I can.

Thank you.

[The prepared opening statement of Mr. Boehlert follows:]

HON. SHERWOOD BOEHLERT (R-NY)
OPENING STATEMENT
SCIENCE EDUCATION HEARING
March 9, 1989

Mr. Chairman:

Of all the topics we will discuss this year, none is as important, none is of greater concern to the general public than the one which will engage us this morning. And for good reason. Our public school system functions like the "canary in the coal mine," alerting us to grave dangers that threaten our economy and our society.

We have convened this morning to diagnose and develop cures for one very sick canary. The sources of that illness are numerous, but I believe that more than anything else, the canary has been choking from the atrophying of America's teaching profession.

The future success or failure of America's schools will be determined in large part by the quality of their teachers. After all, when each of us looks back on our own schooling, we realize it's the outstanding teachers that made the difference -- not outstanding textbooks or lab equipment or computers. Good teachers have a chance of triumphing over even the worst conditions; bad teachers can fail even in the kindest, gentlest environment.

But where are the good teachers of the future? We can no longer depend on a once-reliable source -- women who had no other opportunities open to them.

The statistics paint a dire picture. Students declaring an interest in teaching are among the lowest scorers on SAT exams. Schools are finding it difficult to fill math and science teaching positions. Increasingly, high school math and science courses are taught by teachers with little or no training in those fields, and the situation is worse at the elementary level. In New York City, for example, one in every three science teachers is teaching without a specialized license.

People used to joke that "those who can't do, teach." But we're in real trouble when those who can't teach, teach. Or still worse, when those who can't learn, teach.

Yesterday, I introduced a bill designed to attract more top students into this critical profession. The bill would offer federal scholarships of $7,500 to college juniors and seniors majoring in science, math or engineering if they agreed to teach two years for each year they received the aid.

This is the type of action we need if we are to reverse the steady deterioration of our schools. We have sat back too long as the evidence of a crisis has mounted. It seems at time that we almost take a perverse pleasure in the issuance of each new report documenting our demise, reveling in its familiarity. We have spent too much time, in the words of one critic, "amusing ourselves to death."

Rather than being daunted by the overwhelming nature of our task, we need to be inspired by the optimism and idealism of another time of educational challenge. John Kennedy's words should propel us: "All this will not be finished in the first one hundred days. Nor will it be finished in the first one thousand days....But let us begin."

Our distinguished witnesses today, especially the teachers, will help us decide how to make that beginning. But we must act.

Mr. Chairman, Thomas Jefferson once wrote that the problem of slavery awakened him "like a fire bell in the night." Well, education is the central question of our day just as slavery was in Jefferson's -- the issue that will determine the future structure of our society and the health of our economy.

Too many Americans decided to sleep through the alarm that Jefferson heard so crisply, and we are still paying the price. If we fail to respond to the growing alarm about our public schools, the effect will be equally devastating.

Thank you.

Mr. WALGREN [presiding]. Thank you very much, Mr. Boehlert, and we certainly understand.

I want to apologize for not being able to be here at the outset. The traffic is terrible in this city and very unpredictable.

But you know I want to encourage you in every way in your interest in science education along with all the other members in any way that I can, and I look forward to this committee reporting out legislation in this area in the very near future, and it will be in many ways because of the very personal interest that you and others have taken in this area.

Mr. BOEHLERT. Thank you, Mr. Chairman.

Mr. WALGREN. So we look forward to doing this together.

Let me ask unanimous consent that my statement be inserted in the record at this point.

[The complete opening statement of Mr. Walgren follows:]

OPENING STATEMENT OF THE HONORABLE DOUG WALGREN (D-PA) ON OVERSIGHT HEARING ON SCIENCE AND MATHEMATICS EDUCATION

March 9, 1989

THIS MORNING WE WILL EXPLORE WHAT IS POSSIBLY THE MOST SERIOUS LONG-TERM PROBLEM FACING OUR NATION -- SCIENCE EDUCATION. WE WILL FOCUS ON NATIONAL SCIENCE FOUNDATION PROGRAMS DESIGNED TO IMPROVE PRECOLLEGE SCIENCE AND MATHEMATICS EDUCATION AND ON RECENT LEGISLATIVE PROPOSALS FROM TWO OF MY COLLEAGUES AND MYSELF FOR UNDERGRADUATE SCHOLARSHIPS IN SCIENCE, MATHEMATICS AND ENGINEERING.

THE CRISIS IN SCIENCE EDUCATION IS DRIVEN HOME TO US IN AN UNRELENTING TORRENT OF BAD NEWS:

- AMERICAN FIFTH GRADERS FALL FAR BEHIND JAPANESE STUDENTS IN SCIENCE AND MATH PROFICIENCY.
- AMERICAN 13-YEAR OLDS SCORE BEHIND SPAIN AND SOUTH KOREA IN STANDARDIZED MATH TESTS.
- NEARLY HALF OF AMERICAN 17-YEAR OLDS CANNOT PERFORM MATH PROBLEMS NORMALLY TAUGHT IN JUNIOR HIGH SCHOOL.
- STANDARDIZED TEST SCORES OF AMERICAN ADVANCED PLACEMENT HIGH SCHOOL STUDENTS ARE LAST IN A 17 NATION FIELD IN BIOLOGY AND THIRD FROM LAST IN CHEMISTRY.

THESE DISMAL FINDINGS ARE ESPECIALLY DISTURBING AT A TIME WHEN WE ARE NOT DOING WELL IN THE INTERNATIONAL ECONOMIC

COMPETITION THAT REQUIRES A TECHNOLOGICALLY LITERATE WORKFORCE AS AN ESSENTIAL ELEMENT. MOREOVER, IF TALENTED STUDENTS ARE NOT TURNED ON TO SCIENCE AND MATH WHILE IN ELEMENTARY AND SECONDARY SCHOOL, WHAT HOPE DO WE HAVE FOR MAINTAINING THE PIPELINE OF SCIENTISTS AND ENGINEERS THAT IS NECESSARY TO SUSTAIN AN ADVANCED INDUSTRIALIZED NATION?

THIS MORNING, WE WILL EXPLORE THE IMPACT AND EFFECTIVENESS OF NSF PROGRAMS FOR THE DEVELOPMENT OF NEW PRECOLLEGE CURRICULAR MATERIALS FOR SCIENCE AND MATHEMATICS INSTRUCTION, AS WELL AS NSF EFFORTS TO IMPROVE TEACHER SKILLS THROUGH IN-SERVICE TEACHER TRAINING PROGRAMS. WE WILL HEAR FROM A VARIETY OF EDUCATORS, TEXTBOOK PUBLISHERS, AND SCIENTISTS. MANY OF OUR WITNESSES HAVE BEEN SUPPORTED BY NSF TO DEVELOP AND DISTRIBUTE NEW TEACHING MATERIALS OR TO IMPROVE THE SKILLS OF PRACTICING TEACHERS. ALSO, WE WILL HEAR FROM TEACHERS WHO HAVE PARTICIPATED IN NSF PROGRAMS AND HAVE USED MATERIALS GENERATED BY NSF PROGRAMS.

ANOTHER PURPOSE OF THIS HEARING IS TO OBTAIN COMMENTS FROM INTERESTED GROUPS ON LEGISLATIVE INITIATIVES WHICH WOULD REQUIRE NSF TO ADMINISTER UNDERGRADUATE SCHOLARSHIP PROGRAMS. THE BROAD PURPOSE OF THE PROPOSED LEGISLATION IS TO ATTRACT MORE STUDENTS TO CAREERS IN SCIENCE AND

ENGINEERING OR IN SCIENCE AND MATH TEACHING. CONGRESSIONAL SCHOLARSHIPS WILL RAISE THE PUBLIC'S ATTENTION TO THE IMPORTANCE OF SCIENCE TO OUR NATIONAL WELL BEING IN ADDITION TO ENCOURAGING INDIVIDUALS TO PURSUE CAREERS IN SCIENCE. WE LOOK FORWARD TO THE DISCUSSION OF THESE EDUCATION INITIATIVES.

OUR FIRST WITNESS IS DR. ERNEST BOYER, PRESIDENT OF THE CARNEGIE FOUNDATION FOR THE ADVANCEMENT OF TEACHING. DR. BOYER, A FORMER U.S. COMMISSIONER OF EDUCATION, IS A DISTINGUISHED EDUCATOR WHO WILL PROVIDE US WITH AN OVERVIEW OF THE CURRENT STATE OF PRECOLLEGE SCIENCE AND MATHEMATICS CURRICULA AND ALSO THE TRAINING NEEDS OF SCIENCE AND MATH TEACHERS.

TO OUR PANEL ON CURRICULAR MATERIALS WE WELCOME MS. BETTY CASTOR, THE FLORIDA COMMISSIONER OF EDUCATION; MR. PATRICK DONAGHY, PRESIDENT OF THE SCHOOL GROUP AT SILVER, BURDETT AND GINN; AND MR. RONALD MALONE, PRESIDENT OF KENDALL/HUNT PUBLISHING COMPANY, ACCOMPANIED BY LARRY LOEPPKE, ASSISTANT VICE PRESIDENT AT KENDALL/HUNT.

TO OUR PANEL ON IN-SERVICE TEACHER TRAINING WE WELCOME DR. JERRY BELL, PROFESSOR OF CHEMISTRY AT SIMMONS COLLEGE; MS. MARJORIE BARDEEN, PROGRAM DIRECTOR FOR FRIENDS OF FERMILAB

AT THE FERMI NATIONAL ACCELERATOR LABORATORY; AND DR. PAUL SALTMAN, PROFESSOR OF BIOLOGY AT THE UNIVERSITY OF CALIFORNIA - SAN DIEGO.

TO OUR PANEL OF TEACHERS WE WELCOME MR. LORING COES, III FROM ROCKY HILL SCHOOL IN GREENWICH, RHODE ISLAND; MS. JOANN MOSIER FROM FAIRDALE HIGH SCHOOL IN FAIRDALE, KENTUCKY; AND MRS. JOYCE KERANEN FROM COOPER INTERMEDIATE SCHOOL IN MCLEAN, VIRGINIA. WE CONGRATULATE MR. COES AND MS. MOSIER ON THEIR RECENT PRESIDENTIAL AWARDS FOR EXCELLENCE IN MATHEMATICS AND SCIENCE TEACHING.

TO OUR FINAL PANEL ON PROPOSED LEGISLATION WE WELCOME DR. RICHARD ATKINSON, PRESIDENT OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE; PROFESSOR LYNN ARTHUR STEEN, CHAIRMAN OF THE COUNCIL OF SCIENTIFIC SOCIETY PRESIDENTS; AND DR. THOMAS MALONE, PRESIDENT OF SIGMA XI, THE SCIENTIFIC RESEARCH SOCIETY.

Mr. **Walgren**. And can I ask if there are other members who would like to make opening statements?

Mr. Slaughter.

Mr. **Slaughter**. Mr. Chairman, I would like to make a brief statement.

Mr. **Walgren**. Certainly.

Mr. **Slaughter**. Mr. Chairman, I have introduced a bill, H.R. 1217, that a number of people here are familiar with, so I will not repeat everything that I have in my statement.

First off, this is a bill, of course, to promote the study of engineering, mathematics and the life and physical sciences. This legislation provides scholarships for the most academically qualified, competitive and interested college juniors. In addition to two years of undergraduate support, these scholarships will grant two years of graduate financial assistance to those recipients most qualified to pursue additional post-graduate studies.

Specifically, my legislation will provide up to $5,000, $10,000 in federal funds and $5,000 in matching university funds, in annual financial assistance to 1,500 college juniors and 1,500 seniors. Scholarship recipients will be able to use their scholarships toward undergraduate degrees in engineering, mathematics, and the life and physical sciences.

Upon graduation from an accredited institution of higher education, those students wishing to continue their education by pursuing graduate degrees will compete for one of the 900 scholarships available to first-year graduate students, thereby creating a bridge for the student to cross between undergraduate and post-graduate study.

In return for this scholarship, recipients will be called upon to use their technological skills and knowledge for summer and post-graduate service in a science, mathematics or engineering-related capacity in the employ of the United States, or with an organization performing services for the United States.

Through this program the government would invest in the academic pursuits of certain able students by providing financial incentives for them to continue their education in fields that are critically important to the nation in return for this service.

I commend the Chairman for convening this oversight hearing on National Science Foundation educational programs that strive to fill the technological and educational gap between the United States and our competitors. I am pleased that we have before us this morning a distinguished panel of experts and witnesses to discuss the progress of existing programs under the auspices of the National Science Foundation, as well as provide insight regarding the merits of legislative proposals currently before this subcommittee, and I look forward to hearing from them.

Thank you, Mr. Chairman.

[The prepared opening statement of Mr. Slaughter follows:]

OPENING STATEMENT OF THE
HONORABLE D. FRENCH SLAUGHTER, JR. (VA)
FOR
NATIONAL SCIENCE FOUNDATION OVERSIGHT HEARING
BEFORE THE HOUSE SUBCOMMITTEE ON SCIENCE, RESEARCH, AND TECHNOLOGY
MARCH 9, 1989

The United States may be surpassed by foreign nations in the technological arena due in large part to an ever-increasing shortage of qualified scientists, mathematicians and engineers. This technological shortage is posing a threat to the welfare of the American economy and to our national security as well.

In order to meet the enormous challenge of this growing technology gap, I have introduced the Science, Mathematics and Research Technologies Scholarships Act.

To promote the study of engineering, mathematics, and the life and physical sciences, this legislation provides scholarships for the most academically qualified, competitive and interested college juniors. In addition to two years of undergraduate support, these scholarships will grant two years of graduate financial assistance to those recipients most qualified to pursue additional post-graduate studies.

Specifically, my legislation will provide up to $ 5 000 ($10,000 in Federal funds and $5,000 in matching university funds) in annual financial assistance to 1,500 college juniors and 1,500 seniors. Scholarship recipients will be able to use their scholarships toward undergraduate degrees in engineering, mathematics and the life and physical sciences. Upon graduation from an accredited institution of higher education, those students wishing to continue their education by pursuing graduate degrees will compete for one of the 900 scholarships available to first year

GRADUATE STUDENTS, THEREBY CREATING A BRIDGE FOR THE STUDENT TO CROSS BETWEEN UNDERGRADUATE AND POST-GRADUATE STUDY. GRADUATE SCHOLARSHIP RECIPIENTS COULD RENEW THIS SCHOLARSHIP FOR ONE ADDITIONAL YEAR OF POST-GRADUATE STUDY, IF NECESSARY.

IN RETURN FOR ONE OF THESE MERIT SCHOLARSHIPS, RECIPIENTS WILL BE CALLED UPON TO USE THEIR TECHNOLOGICAL SKILLS AND KNOWLEDGE FOR SUMMER AND POST-GRADUATE SERVICE IN A SCIENCE, MATHEMATICS OR ENGINEERING RELATED CAPACITY IN THE EMPLOY OF THE UNITED STATES OR WITH AN ORGANIZATION PERFORMING SERVICES FOR THE UNITED STATES. THUS, THROUGH THIS PROGRAM, THE GOVERNMENT WOULD INVEST IN THE ACADEMIC PURSUITS OF CERTAIN BRIGHT STUDENTS BY PROVIDING FINANCIAL INCENTIVES FOR THEM TO CONTINUE THEIR EDUCATION IN FIELDS THAT ARE CRITICALLY IMPORTANT TO THE NATION IN RETURN FOR THIS SERVICE.

I COMMEND THE CHAIRMAN FOR CONVENING THIS OVERSIGHT HEARING ON NATIONAL SCIENCE FOUNDATION EDUCATIONAL PROGRAMS THAT STRIVE TO FILL THE TECHNOLOGICAL AND EDUCATIONAL GAP BETWEEN THE UNITED STATES AND OUR COMPETITORS. I AM PLEASED THAT WE HAVE BEFORE US THIS MORNING A DISTINGUISHED PANEL OF EXPERTS AND WITNESSES TO DISCUSS THE PROGRESS OF EXISTING PROGRAMS UNDER THE AUSPICES OF THE NATIONAL SCIENCE FOUNDATION, AS WELL AS PROVIDE INSIGHT REGARDING THE MERITS OF LEGISLATIVE PROPOSALS CURRENTLY BEFORE THIS SUBCOMMITTEE, AND I LOOK FORWARD TO HEARING FROM THEM.

# # #

Mr. **Walgren**. Thank you, Mr. Slaughter.

Are there other members who would like to make opening comments?

Mr. Campbell.

Mr. **Campbell**. Thank you, Mr. Chairman.

I also commend you for holding these hearings. I will take perhaps 20 seconds only to say that I would be ungrateful as well as unobservant if I did not note that in my own personal career funding from the National Science Foundation helped me get my education and helped me as a professor, and I would like to do everything I can to assist that continuation of that program.

Thank you.

Mr. **Walgren**. Well, we look forward to building on that real world experience.

Our first witness is Dr. Ernest Boyer, the President of the Carnegie Foundation for the Advancement of Teaching.

Dr. Boyer is a former U.S. Commissioner of Education and a distinguished educator, who will provide us with an overview of the current state of precollege science and math curricula and also the training needs of science and mathematics teachers, and while Dr. Boyer is taking his place at the table, let me just preview the other two panels.

The second panel will be on curriculum materials. It will include Betty Castor, the Florida Commissioner of Education; Dorothy Shao, the Executive Editor at Silver, Burdett and Ginn, one of the major publishers in this area; Ronald Malone, the President of Kendall/Hunt Publishing Company, who will be accompanied by Larry Loeppke, who is Assistant Vice President at that organization.

And then we will have a panel on in-service teacher training, which will include Dr. Jerry Bell, Professor of Chemistry at Simmons College; Marjorie Bardeen, the Program Director for the Friends of Fermilab at the Fermi National Accelerator Laboratory; and Dr. Paul Saltman, Professor of Biology at the University of California-San Diego.

We will follow that with a panel of teachers, including Loring Coes, from Rocky Hill School in Greenwich, Rhode Island; Jo Ann Mosier from Fairdale High School in Fairdale, Kentucky; Joyce Keranen, from Cooper Intermediate School in McLean, Virginia, and we particularly want to note that Mr. Coes and Ms. Mosier have recently received Presidential Awards for Excellence in Mathematics and Science Teaching.

And then we will last have a panel commenting on a number of pieces of the proposed legislation that are before the committee—Dr. Richard Atkinson, President of the American Association for the Advancement of Science; Professor Lynn Arthur Steen, Chairman of the Council of Scientific Society Presidents; and Dr. Thomas Malone, the President of Sigma Xi, will join us on that panel.

Well, obviously, it is a full day and, as is our custom, I want to say at the outset that written statements will be reproduced in full in the manner in which these proceedings are transcribed and printed. So full statements will be there for those who work with these transcripts without further effort, and witnesses can feel free to focus on points that they would like to highlight by targeting them in their oral presentation if that is the way they would like to approach it.

We need to keep our witnesses, obviously, to some time frame between five and 10 minutes, or else the hearing just goes on forever, and the members have commitments in the noon hour and the like. So we have to be strict with that.

So with asking your understanding on that level, I want to express our appreciation to all of you for coming and helping us in this process, and I recognize you, Dr. Boyer, for your testimony.

STATEMENT OF DR. ERNEST L. BOYER, PRESIDENT, CARNEGIE FOUNDATION FOR THE ADVANCEMENT OF TEACHING, PRINCETON, NJ

Dr. Boyer. Thank you very much, Mr. Chairman. I am grateful for the opportunity to testify before this distinguished committee, and I also commend you for assembling the hearing that you have done on a topic that I think is of such vital importance to the nation.

This morning I have been asked to summarize very briefly in my formal testimony matters relating to the status of science and mathematics teaching in the nation's public schools.

The harsh truth is that science and mathematics education in the United States is in bad shape. The recent National Academy of Science report, called "Everybody Counts," reached the chilling conclusion that in a world where technological literacy is absolutely crucial the majority of our students do not have the mathematical power they need to live productive lives.

The report also revealed the shocking shortage of qualified mathematics teachers, the point we just heard, and in fact there is probably a greater shortage in mathematics teachers than in any other field and, as everyone knows, mathematics is the fundamental tool for science and technology later on.

The recent National Assessment Report also painted a picture that was very bleak when the math proficiency of 13-year-olds in the United States were compared. Their proficiency was compared with students in five other countries. Almost all 13-year-olds could add and subtract, which is about as basic as you can get; however, only 40 percent could do two-step problems in mathematics and only 9 percent could understand fundamental mathematics concepts. Compare that to 40 percent of the 13-year-olds in Korea.

At this point perhaps some good news is in order. Last year at the Carnegie Foundation we asked 2,000 fifth graders which subject they liked best. I guess I have to tell you I was surprised when mathematics came out first.

This suggests to me that the proverbial "I hate math" syndrome is not something that students actually have as an attitude. It is in fact something that they learn in school.

In science the picture is equally disturbing. The National Assessment Report indicates that only 7 percent of the nation's 17-year-olds have knowledge they need to perform in college level science, and an international comparison is even more distressing. At grade 5 U.S. students ranked in the middle in general science knowledge compared to 14 other countries. At grade 9, however, they ranked last.

And in advanced biology U.S. students were also at the bottom.

I could continue, but I do not wish to engage in the perverse practice we have just been warned about; namely, to take delight in describing in vivid detail the nature of our problem.

I do wish to say, however, that I believe this strikes at the heart of the intellectual vitality of this nation, and I believe it is time for a national strategy to be developed.

I believe, for example, that the House resolution we have just heard about is a big step in the right direction. The Congressional Scholarship Program you propose would send precisely the right signal to the nation. The number of students to be selected in this program is of course very small, but again the signal would be very clear, and I would hope that in the future the program to give scholarships to students who plan to go into teaching could be expanded.

Another piece of legislation pending before this committee would provide scholarships for outstanding math and science students during the last two years of college, about which we have just heard. In return the student would work in a science or engineering capacity for the government for several years.

In my opinion, this legislation would develop more scientific talent at the top while energizing great benefits for the nation, too.

In my conclusion, then, in this overview, Mr. Chairman, I should like to give you a few prejudices of my own as to the kind of strategy we need in response to the crisis that we have just defined, and I have a six-step suggestion to submit.

First, let me say a word about the curriculum.

The hard truth is that with all the talk about better schools we still do not have coherent math and science curriculum for the early and middle years. We are still confused about what all students should know and be able to do in these essential fields.

We have in the past few years in almost every state been including another requirement in math and in science, another Carnegie Unit, a term, incidentally, that my foundation unhappily created 60 years ago, but the honest fact is that we are often unclear as to what we mean by another unit in science or mathematics. So students complete the credits, but there is no assurance that they acquire knowledge.

Here I have a rather brash proposal to suggest. I suggest we consider creating a kind of peacetime Manhattan project on school curriculum, with perhaps special emphasis on science and mathematics, a program that would bring together master teachers and research scholars, giving them time off to think with some continuity about what it is we wish to be teaching and what the sequence of the curriculum should be beginning in the early years where the foundation must be laid.

The aim would be to design an appropriate course sequence in math and science, not just for the specialist but for the non-scientist as well.

Frankly, Mr. Chairman, I find it ironic that six years after we decided the nation was at risk the nation still has not adequately responded. We are still trying to figure out what students need to know, and I believe a national effort in this regard, funded perhaps through the NSF, would allow us perhaps to bring together both the practitioner and the theorist to begin to redesign a curriculum structure for the year 2000 and beyond. Simply building a curriculum based on textbooks is not sufficient.

Second, I think we must give more dignity and more status to the teacher because, as we have just heard in that splendid opening statement by Mr. Boehlert, we can have excellence in education only when we understand that we need excellence in teaching, and until we get the brightest and the best to enter teaching, until we can attract those who routinely go into medicine, business, and law to come into the classrooms of this nation, our search for excellence frankly will be only a diversion. It cannot be dictated from the top. It cannot be legislated from on high. It has to be inspired in the classroom by those who know their subjects and can convey it inspirationally to their students.

Now, some of the nation's colleges offer scholarships, full scholarships to outstanding high school students to agree to teach after graduation. I think more colleges should follow these examples, and, incidentally, I think we might give special incentives to those who agree to teach in math and science, perhaps giving them summer institutes in which they could work with some of the most gifted math and science scholars in the nation, and I wonder if the federal government might not have a special matching scholarship fund that would be available to those colleges that would wish to recruit young gifted students who themselves pledge to go into teaching after graduation.

After all, as we have just heard, we recruited the Peace Corps young people to be in service overseas. Why not inspire young people to go into the classrooms here in the United States?

This to me is the challenge in the decade of the '90s.

This leads me to proposition number three.

We need to rearrange the curriculum. We need to attract outstanding teachers. But, third, I think we need programs of alternative certification, not just for the young but for older people, too.

I am convinced that we should attract outstanding math and science teachers from those who are mid-career or even those who are near retirement. This is a huge pool of talent that is often neglected, and one way to do it is to encourage states to develop an alternative certification which allows mid-career people to come into the classroom without going into a traditional teacher training program.

I don't have to remind you that New Jersey has led the way in this regard, and I think the record shows that in the past five years they have attracted an outstanding pool of gifted teachers who, based on all the data, are as effective and even more so as those who have come up through the traditional route.

We need industry and business, then, to be partners in the process, and I think we can find a great pool of outstanding teachers through alternative certification.

That leads me to issue number four.

We need in-service training, too, because in the end it is the teachers who are already in the classroom who need urgently to be inspired, and yet the truth is that they have to stay in those classrooms year after year, they are not intellectually renewed, and somehow we expect them to keep giving out year after year.

Three decades ago, after Sputnik, President Eisenhower concluded that strengthening math and science teachers already in the schools was the key to national security, and he secured passage of the National Defense Education Act, a program which, as you know, provided summer fellowships for teachers.

And, frankly, when I go around the country I am impressed that I will still, 30 years later, hear a teacher tell with great enthusiasm I had an NDA fellowship and it changed my life, and not only did they get inspired, when they would go back to school they would inspire others, too.

I think we miscalculate mightily the essential need of continuing to renew the teachers who meet with children every single day.

I think, therefore, an NDEA type program today should be carefully considered because teachers who are now in school remain our greatest resource for improving the performance of our students. Strengthening their skills, in my judgment, should be a top priority, especially in math and science.

This brings me to prejudice number five.

I concur entirely that great teachers can overcome even bad equipment, but I have to pause, especially in math and science, to talk about the condition of science and math facilities in our public schools.

Two years ago at the Carnegie Foundation, we did a study of urban education. We went into dozens of high schools in the ten largest cities in this country, and all I can tell you is that the science laboratories in most high schools in the United States is a national disgrace. You go into most of these places, you will find broken test tubes, outdated manuals, Bunsen burners that won't work.

I read in the New York Times the man who is trying to push his video program in the school, and in justifying that he said that he was in some schools or knew of schools where they used popcorn poppers as Bunsen burners.

It is almost laughable for us to talk about becoming competitive technologically in the twenty-first century when our future scientists are working in the conditions that we provide them. I believe that we not only have to inspire teachers, we have to give them decency and some recognition of the basic facilities that they need to teach basic science to our students.

I remember, Mr. Chairman, following World War II, when we had a big push of college students and the federal government had a Facilities Act that gave low interest loans to colleges from coast to coast to permit them to build buildings so they could accommodate expanding enrollments. This institution, Congress, provided aid to colleges so they could build buildings.

It occurred to me that we perhaps need a 1990 version of the Facilities Act. This would be directed toward high schools so they could refurbish science labs.

This was a low interest loan program, and based upon the budgets in most of these cities, they can hardly heat the place, let alone refurbish the facilities for science and mathematics.

I suggest that the federal government may wish to consider a low interest loan program, making available to school districts money to allow them to have state-of-the-art facilities in order to stimulate state-of-the-art minds for Century 21.

Then, finally, in item six, I would like to just say a passing word about specialty residential schools in science and mathematics, such as the one in North Carolina.

I don't think that this approach is needed in every state, but I do believe where resources are limited it makes sense to bring the most gifted math and science students and teachers together to build an elite corps of scientists that we will need in the international high tech race in the year 2000 and beyond, when mind power will be absolutely crucial.

It is not unthinkable that we could have federal leadership in providing centers of mathematics instruction that would be used perhaps for the school year, but they also could be centers for in-service training in the summer, where we could have the brightest and the best come together to work together under ideal conditions so we could prepare an elite corps of leaders in the nation.

I simply conclude, Mr. Chairman, by saying we have an absolutely critical problem in an area in which I believe the future of the nation will be pivoted. I do not believe that we can achieve excellence piecemeal. I think a program here and there simply will not do the trick, and I would like to see under the leadership of this distinguished committee a comprehensive program, one that involves the curriculum, one that involves recruiting and inspiring teachers, and one that involves facilities upgrading to help us maintain our competitive advantage.

And, incidentally, I think NSF provides an absolutely splendid structure for the leadership in this direction, and I commend them for their work because they are focusing both on curriculum and on teachers.

Thank you very much for giving me the opportunity to appear with you today, and I will be pleased to respond to any questions you may have.

[The complete prepared statement of Dr. Boyer follows:]

THE STATUS OF MATH AND SCIENCE EDUCATION

Testimony of
Ernest L. Boyer
President

The Carnegie Foundation for
the Advancement of Teaching

Subcommittee on Science, Research and Technology
U.S. House of Representatives

March 9, 1989

Thank you, Mr. Chairman, for the opportunity to testify before this distinguished committee. Your work is crucial to the future of the nation.

Five years ago, the Carnegie Foundation, in its report High School, urged that all students in the public schools complete a core curriculum, one that emphasized science, technology, and mathematics.

We said that "Not all students are budding science scientists, but becoming a responsible citizen in the last decade of the twentieth century means that everyone must become scientifically literate."

We also urged that "all students should expand their capacity to think quantitatively and to make intelligent decisions regarding measurable quantities."

Our core curriculum proposes a minimum of two years of science and mathematics for all students, along with at least a semester-long study of technology. For students who plan to become scientists and engineers, more advanced courses would be needed.

Mr. Chairman, in addition to training top mathematicians and high level scientists, we also desperately need a well-informed citizenry, one conversant with how science and math works. Professor Jeremy Bernstein has put it well:

> "We live in a complex, dangerous and fascinating world. Science has played a role in creating the dangers, and one hopes that it will aid in creating ways of dealing with these dangers. But most of these problems cannot be dealt with by scientists alone. We need all the help we can get, and this help has got to come from a scientifically literate general public.. Ignorance of science and technology is becoming the ultimate self-indulgent luxury."

The harsh truth is that science and mathematics education in the nation's schools is in bad shape. The National Academy of Sciences' Committee on Mathematical Sciences in the Year 2000 on which I serve reported that mathematics education in the United States is facing major challenges on nearly every front:

- Far too many students, including a disproportionate number from minority groups, leave school without having acquired the mathematical power necessary for productive lives.

- When compared with students of other nations, U.S. students lag far behind in levels of mathematical accomplishment; the resulting educational deficit reduces our ability to compete in international areas.

- The shortage of qualified mathematics teachers in this country is more serious than in any other area of education, from elementary school to graduate school.

- At the college level, undergraduate mathematics is intellectually stagnant, overgrown with stale courses that fail to stimulate the mathematical interests of today's students.

Let me add one other telling concern: The report concludes that, "the least effective mode for mathematics learning is the one that prevails in most of America's classrooms: lecturing and listening."

Teachers will simply have to more actively engage students in the learning process. This does not simply apply to mathematics alone, but across the board. In mathematics, though, good education means not just the recall of isolated facts, but searching for solutions; not just memorizing formulas, but getting students to think creatively. And frankly, this is not happening today.

Turning to another source, the most recent National Assessment of Educational Progress (NAEP) report--Crossroads in American Education--also presents a dark picture of mathematics achievement among our students (Attachment A):

- The report reveals that most nine, thirteen, and seventeen-year-olds can do simple tasks, like add and subtract. But the majority don't know how to apply knowledge to more complex questions.

- "By and large," the report declares, "students are learning the basics, and black and Hispanic students are closing the historical gap in performance with their white peers. Yet despite these signs of progress, it remains true that only some of the nation's students can perform moderately difficult tasks and woefully few can perform more difficult ones."

Let me add one bit of information that offers hope. Last year, in connection with a study the Carnegie Foundation is preparing on the early years of learning, we asked a sample of fifth graders what subject they liked most among their courses. Guess what? Mathematics came in first, with 25 percent. Among eighth graders, 17 percent said math was their favorite subject, second only to physical education at 18 percent.

This survey suggests that the proverbial "I hate math" one too often hears does not reflect the attitudes of students. What it also suggests is that we surely must find better ways to fan the fire of each interest and keep students from being turned off in mathematics.

In science, the crisis is equally disturbing. Again, NAEP's most recent Science Report Card--Trends and Achievement Based on the 1986 National Assessment reports that:

- More than half of the nation's seventeen-year-olds appear to be inadequately prepared either to perform competently jobs that require technical skills or to benefit substantially from specialized on-the-job training.

- The thinking skills and science knowledge possessed by these high-school students also seem to be inadequate for informed participation in the nation's civic affairs.

- Only 7 percent of the nation's seventeen-year-olds have the knowledge and skills needed to perform well in college-level science courses. Since high-school science proficiency is a good predictor of whether or not a young person will elect to pursue postsecondary studies in science, the probability that many more students will embark on future careers in science is very low.

International comparisons also are distressing. A recent science assessment reveals that U.S. students are among the lowest achievers of all participating countries (Attachment B):

- At grade five, our students ranked in the middle in science achievement relative to fourteen other participating countries.

- At grade nine, they ranked next to last.

- In the upper grades of secondary school, "advanced science students" in the U.S. ranked last in biology.

- U.S. students also performed behind students from most countries in chemistry and physics.

Students do not all arrive at the kindergarten door with equal opportunities and aspirations. Social and economic realities have begun to have an impact long before that time, and schooling does not serve to eradicate these inequities, NAEP emphasizes.

The data show substantial disparities in science proficiency between groups defined by race and ethnicity:

- Despite recent gains, the average proficiency of thirteen and seventeen-year old black and Hispanic students remains at least four years behind that of their white peers.

- Only about 15 percent of the black and Hispanic seventeen-year-olds in 1986 demonstrated the ability to analyze scientific procedures and data, compared to nearly one-half of the white students this age.

Frankly, Mr. Chairman, the evidence is overwhelming. There is an absolutely crucial need in this country to strengthen mathematics and science education for all students. The need is especially acute for minority youngsters who by the year 2000 will constitute roughly 40 percent of public school enrollment; when they fail, the nation fails.

One way of enlarging the talent pool of potential mathematicians and scientists is to ensure that all students get an equal start. Instilling basic skills for all children early on is vital.

In this connection, Mr. Chairman, I'd like to add that those proven effective federal programs that serve disadvantaged students, such as Head Start and Chapter One, still serve less than half of those eligible.

Finally, I'd like to comment briefly on the legislation pending before your committee that seeks to tackle the shortcomings in math and science.

H.R. 996 is clearly a step in the right direction. The congressional scholarship program you propose sends precisely the right message--namely, that America cares about having the math and science talent it needs to move confidently into the next century.

The number of students to be selected--two to a congressional district--is limited. Still, it sends a clear signal that math and science teaching is critically important and I'd hope that as future budgets permit, this important effort could be expanded.

I also like the idea of giving awards to students who commit themselves to teach math and science in the schools. Something must be done to stop the decline in qualified math and science teachers. This is a national problem that requires a national response.

Some of the nation's colleges and universities are already providing scholarships for outstanding high school graduates who commit to teaching. A federal effort to join with such institutions in helping to expand the number of top math and science teachers is a strategy worth pursuing.

One last point. Three decades ago, following the Soviet's launch of Sputnik, President Eisenhower concluded that strengthening math and science in the schools was the key to our national security, and he secured passage of the National Defense Education Act. The program provided fellowships for teacher upgrading and renewal in these critical fields on campuses across the nation.

An NDEA-type program today would supplement and add to the legislation under consideration in a powerfully important way. Teachers who are now in the schools remain our greatest resource for improving student performance. Strengthening their skills should be a top priority, too.

Mr. Chairman, thanks very much for the opportunity to meet with you today. I'll be pleased to answer any questions you and other committee members may have.

Attachment A

TABLE 1.1

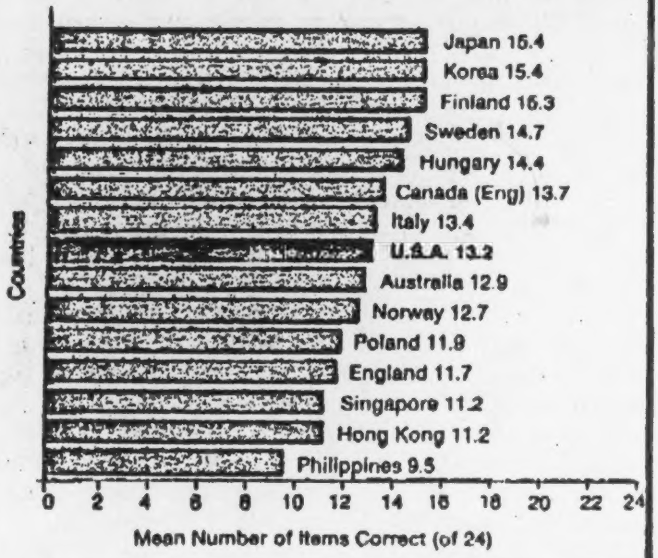
Percentages Performing At or Above Each Level of the Mathematics Scale, Age 13*

LEVEL ▸	Add and Subtract 300	Simple Problems 400	Two-Step Problems 500	Understand Concepts 600	Interpret Data 700
Korea	100	95	78	40	5
Quebec (French)	100	97	73	22	2
British Columbia	100	95	69	24	2
Quebec (English)	100	97	67	20	1
New Brunswick (English)	100	95	65	18	1
Ontario (English)	99	92	58	16	1
New Brunswick (French)	100	95	58	12	<1
Spain	99	91	57	14	1
United Kingdom	98	87	55	18	2
Ireland	98	86	55	14	<1
Ontario (French)	99	85	40	7	0
United States	97	78	40	9	1

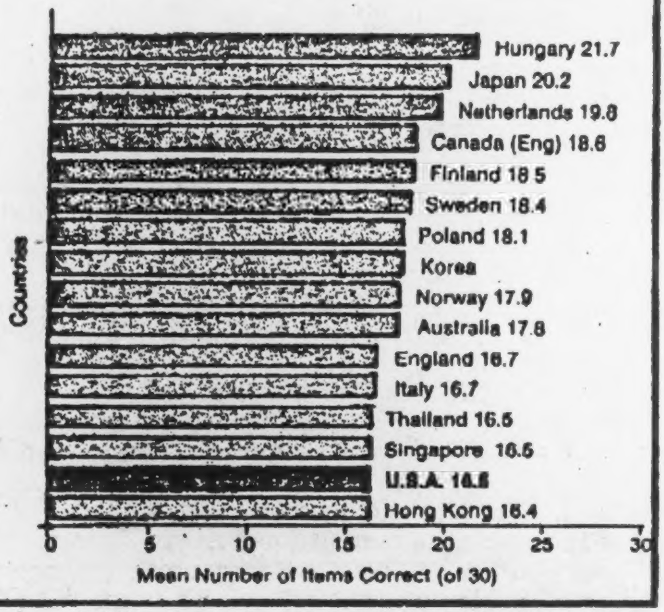
*Jackknifed standard errors for percentages range from less than .1 to 2.4 and are provided in the Data Appendix.

Attachment B

Grade 5 Science Achievement in 15 Countries



Grade 9 Science Achievement in 16 Countries



SOURCE: International Association for the Evaluation of Educational Achievement

Mr. WALGREN. Thank you, Dr. Boyer, for that presentation.

What has gone wrong? Why?

You have commented here we are six years after "A Nation at Risk," and we are still at risk, and I guess I had the impression that NSF has been working on curriculum ever since I came to the Congress, and yet here we are a decade later saying we are still at the point of, in your view, not having decided what it is we ought to teach and how the curriculum ought to do it.

Can you share any thoughts with us about why we haven't made more progress because certainly there have been people across the political spectrum when it comes to education wanting to do the right thing on all levels of government?

Dr. BOYER. We are confused about who is in charge, and American education has grown up grass roots around local districts, and that worked at a time when we were well-funded and had great local school support. But it emerged very unevenly.

Slowly but surely, and especially in the last 10 to 15 years, we have become aware that it is not 16,000 school districts that we are talking about. It is a national strategy, and witness the labeling of that report, "A Nation at Risk."

Now, what we have been doing in our school reform movement—and I don't dismiss it, and, incidentally, we have made great gains. I don't want to be misunderstood and claim that it has been all a waste, but it has not been sufficient.

We have approached it through what I guess I would call excellence by exception. We still follow what I would call the model school approach, the elite school approach, the essential school approach, and if you read the literature it is shot full of the idea we are going to try a model here and there, we are going to try an illustration here and there, but we have not found a way—and I hate to use this word. I am even embarrassed to put it in the record, but I will because it is more than two syllables and therefore suspect—but we have not found a way to have a systemic approach to school excellence; that is, how we can find a way for the entire system to be improved.

We, rather, have used our monies to encourage case studies here and there, but in the end you run out of finding examples unless you also know that you are making available to all.

So what we don't have, frankly, is a framework and a standard against which all schools can be held accountable, and we haven't thought through, as I said earlier, even the curriculum expectation toward which schools can be moving.

So I tell you, I think we are running out of steam on the reform movement because you can only go so far by encouraging one school in isolation to improve itself. We have 83,000 some such schools, and I don't think that is the answer.

I think we need to approach some of these problems through what I guess I would call a systemic approach, and I would say statewide standards but lots of freedom at the local level to implement them and then hold them accountable.

But one of the areas, as I mentioned at the outset, where I think we are still very much confused is to try to think through what we believe the core curriculum should be and what we think the specific content might include, and I think that is where overall leadership is required, giving lots of freedom to the local school and to the teachers, empowering them, then, to implement toward excellence against the framework that has been carefully established.

So we have encouraged, we have not found a way to bring local creativity and national and statewide expectations together.

Mr. **Walgren**. But you would strongly advocate a Manhattan type effort that obviously is on the national level——

Dr. **Boyer**. Yes.

Mr. **Walgren** [continuing]. To decide on goals and to develop——

Dr. **Boyer**. Yes, as models.

Mr. **Walgren** [continuing]. The methods, the specific curriculum to meet that goal?

Dr. **Boyer**. As illustrative models. I am not saying that we need a curriculum that would be imposed on 16,000 districts, but I think we need models and case studies that can be available to indicate how those goals could be established, and I think it is expecting too much to think that each district or local teachers can themselves invent this under the harassed conditions under which they work, but they surely should be involved in developing alternative models that are quite specific as to what the teaching strategies should be so that these could be made available to state departments of education and to local districts, too.

I think it is that kind of creative leadership we need that stops short of a national curriculum rigidly imposed or a national test that would be mandated, but I think there is a middle ground between endless localism, in which, frankly, textbooks and tests determine curriculum.

Mr. **Walgren**. When you say you would stop short of a national curriculum mandated, is the place that you would stop after the word "national curriculum"?

Dr. **Boyer**. It is the "mandated" that I would stop.

Mr. **Walgren**. Mandating is the problem?

Dr. **Boyer**. Yes. But I think it is quite in order in this country to find the middle ground between what—the tension we have in this country. We want local control and we want national results, and we have never found a theoretical model to mediate between the two.

We are slowly shifting away—we are now less concerned about local control, and we are more concerned about national results. What we need now is a new way of procedure in which we give help at the national level that is intellectually exciting, but not take over control and authority that I think would be bureaucratically destructive, and as we have evolved in this country from local control toward national concern, we haven't developed strategies in which we can maintain the two in balance, and so when I stop short is more national leadership to think through goals and to describe by example curriculum using the best minds that we have, not in government but from classrooms and from the world of scholars, and then school districts would have before them the kind of expectation as well as illustration that they need, but not feel that they are going to have to answer to a Secretary of Education down here in the building in Washington.

Incidentally, could I remind you that after Sputnik we had a really exhilarating period of curriculum debate in this country. It was spontaneous, although it got some federal monies. I mean the Mathematics Project, the Biology Project, English Project that involved scholars in the disciplines and schoolteachers that developed some genuinely exciting curriculum framework. Than that all kind of came crashing to a halt during the crisis and the traumas of the '60s.

But we have had much less interest in the intellectual issues of education in this reform movement than we did after Sputnik. Here it has been more structural and more preoccupied with testing.

Following Sputnik we had some very intellectually invigorating efforts on the part of scholars and teachers to try to rethink what it is we should be teaching, and we, I think, need to somehow bring—I guess I would call—the substance of the reform movement into the debate.

But I don't want to just see it by continuing to give grants to isolated efforts. I think we are at a dead end on that. We are going to have to somehow work toward more coherence, but stop short of national mandates.

Mr. WALGREN. The Chair would recognize the gentleman from Virginia, Mr. Slaughter.

I am sorry. Mr. Henry.

Mr. HENRY. Thank you, Mr. Chairman. Thank you, Dr. Boyer.

Just by way of personal background, I used to be a college prof. I come from a family of teachers. I was on the State Board of Education in Michigan, Chair of the Education Committee in the State Senate.

I have got to say you have said more to us coherently and in balance than anything I have heard in the Ed and Labor Committee here in four years in terms of packing a lot into a little.

And I guess I say that not indictively, but in sorrow. Quite frankly, we have had a tremendous problem because of the political dynamics. And I know that if you went into my community most people would agree enthusiastically with what you are saying, but the political endeavor has become so politicized with an agenda of social reform, much of which is so very meritorious, but it is as if the issue of learning in its truest sense has been put at odds with a social agenda of equal educational opportunity in terms of, you know, in the '60s we went through these anguished battles, and appropriately so, in equal educational opportunity for those of color, for those who did not have advantages of wealth in terms of access to higher education, bilingual, multi-cultural, special ed, and that is where the focus has been.

And, at the same time, just to turn back in terms of kind of a vengeful approach to saying now the issue is educational accountability doesn't quite turn the trick either.

Yesterday I had a long meeting with the current Secretary of Education, and we do have the draft of the Administration's certification initiative, and we are waiting for final approval on that, and I will be sure to be in touch with you immediately. I think next week we will have that, and we would appreciate your comments on that.

The one thing that struck me, however, was your first point in terms of the need for curricular reform in the early and middle years.

I have always had kind of a bias that we are losing them in the late middle and high school years. You mentioned early and middle years in terms of curricular reform.

Would you just elaborate on that one point? I would really appreciate it.

Dr. BOYER. Well, in some ways the primary grades are working better than high school in a social sense, and also I think the teaching there is often outstanding. I think if we in this—with all due respect to your prior career—if we would give as much status to first grade teachers as we give the full professors, that one act alone might perhaps renew the nation's schools.

I think the foundation years are absolutely crucial, and I would say that the establishment of language proficiency in the early years is perhaps the key. If I could be assured that by fourth grade all children were proficient in the use of English in both its written and spoken forms, I think we would have done more for the nation's schools than any other intervention that I know.

But having said that, let me hurry on to respond directly to your question. In spite of the fact that I think there are great teachers and that students are often much better supported than in high schools, I have to say from the experience that we have had at Carnegie—and we are doing a report on the early years—by and large there is enormous confusion, and I would say almost—I will not put for the record the word "bankruptcy"—but I would say a lack of understanding as to what the early years are trying to establish in terms of curriculum and what we think students should know in terms of general education.

There was an earlier design which started around the social studies unit, where it started with the child in the family and then a concentric circle to the neighborhood and you took trips to the firehouse and then a concentric circle to your state, kind of moving from the most familiar to the least familiar.

I think that that has become sterile and unuseful. It doesn't indicate how the child develops a larger sense of both social and intellectual connections, and I think the establishment of a core curriculum design at the foundation is absolutely crucial in order for the students then to move out into greater specialization in the senior years and on into high school.

The core of learning and the discovery of connections it seems to me is established in the early years, and I think that is when the child is most ready to see interdependencies and relationships and, frankly, I think is much more intellectually excited at that moment than we give him credit for.

I mean another model—this is now being whimsical—why not start with the universe and move in? My grandchildren talk about galaxies. They don't talk about the firehouse.

I mean, I think we have underestimated what young children are ready to discover in the world around them, and I think we need a fresh and exciting rethinking of the primary school curriculum as the foundation for further learning and specialization. That includes math and science concepts, but other disciplines as well.

Mr. **Henry**. If I may just follow on that, Mr. Chairman, I think it is a very provoking insight. I think perhaps our bias that elementary and middle school works better than high school is kind of a social judgment on the school rather than an academic judgment.

Dr. **Boyer**. And, frankly, the failures in high school are reflecting on what has happened before that. It is not automatically a failure. If you don't develop language proficiency in the early grades, you start to find the failure later on because the demands get greater.

Mr. **Henry**. But I may follow on that.

But as soon as we move into the curricular reforms and the substantive issues we get in a whole issue of cultural elitism. For example, when Mr. Bennett came up with his high school curriculum, which is in some ways what you are talking about, it becomes culturally elitist.

If we look into the elementary, early elementary—and I am not trying to ask a loaded question. I am asking in very good faith—what about Mr. Hirsh's issue on cultural literacy? I mean, does that represent cultural elitism or is he really talking about the protections that make reading work to achieve what you are talking about?

Dr. **Boyer**. Yes. I am going to have to vote on these two people, huh?

I will talk to you over lunch.

Mr. **Henry**. We will do that.

Dr. **Boyer**. No, let me start with Don Hirsh because I think that is a little less volatile in this town.

I have felt for a long time that E.D. Hirsh's basic notion about cultural literacy is sound. If I understand him, what he is saying is we need sufficient common knowledge and sufficient common language and sufficient understanding of common heritage even to engage in discourse, even to argue about our differences.

Mr. **Henry**. And if I understand it, he is saying——

Dr. **Boyer**. There is no way for me to come in here this——

Mr. **Henry** [continuing]. In particular learning the mechanics of reading, but it is senseless because of the lack of that. Once I put that in I am elitist. I am imposing culture.

Dr. **Boyer**. Well, there is a difference between having an understanding that—how shall I say this—look, education has two goals. One is to affirm our individuality and strengthen us and empower us to live as independent autonomous human beings.

The other is to help us discover our connections and to help us understand that there is an interdependency in our existence, and the minute we pretend that there is only one of these that is the minute we have lost the essence of education.

If we stress individuality and say that is all there is, we have miseducated people. On the other hand, if we say that we are all together and deny the differences, then we have also suppressed the dignity of the individual.

All I am saying is we should not put these as tradeoffs because we all live alone and we are all together. We are all independent, and we are all interdependent. We all are isolated, and we are all interconnected.

Now, if that is the reality of life, then education should tell students that you are an individual, we are going to empower you for individual gain, but you are also part of a larger community and there is no way to escape it.

So I think it is a mistake, frankly, to suggest that to talk about common interests is to suppress the distinctiveness of individuals or subgroups. We have to learn to know how to celebrate individuality and our minorities at the same time we have to understand how to build a sense of nationhood that includes those differences.

That is the double mission of a nation and also of education. So I think we are in a terrible bind when to talk about our connectedness is to suggest that we deny differences. On the other hand, to celebrate differences and not identify our points of interconnection is to teach ignorance, not understanding.

Now, as to Mr. Hirsh, he is simply saying we need enough commonality to carry on our common discourse and even to argue about our differences. To that extent, I think his notion of cultural literacy is on track.

He put at the back of his book 5000 items to illustrate what we should know. I think that has been probably a mistake. The list I think is wrong for two reasons. First, it has some things in it I don't know, and, second, I know some things that aren't on the list. So I think it needs to be revised.

But the basic idea that Don Hirsh is arguing about; namely, the fact we need—I mean, the very fact that we are carrying on this hearing is an audacious illustration of cultural literacy. I come in here and go rambling on. I don't even define my proper nouns. I assume, maybe correctly or incorrectly, that something is happening in your cerebrum that matches mine. That is based upon some assumptions of connectedness.

Every time the Washington Post goes out on the street in the morning hundreds of proper nouns are included and they are not defined. The assumption of cultural literacy behind getting out a morning newspaper is absolutely stunning.

So I don't think we can deny the basic principle that we need to have some shared experiences, and that is what education is about. But to do it in the process that would deny differences among us or even to acknowledge that we have sometimes great tensions is where I think education gets off track.

I don't have time to talk about the Secretary.

Mr. WALGREN. We would give you time. [Laughter.]

The gentleman from California, Mr. Brown.

Mr. BROWN. No questions.

Mr. WALGREN. The gentle lady from Rhode Island, Ms. Schneider.

Ms. SCHNEIDER. Let me just add that it is not that I am not in agreement with you that I have no questions. I will say that I have heard more wisdom through your testimony this morning than I have heard in a very long time.

Part of the reason that I was late, I was just returning from a New England Board of Higher Education meeting on biotechnology and its future, and rather than talking about regulatory reform or opening up our competitive markets, the emphasis obviously turned to education. Where is the skilled workforce that we are going to need to carry on our lead in the innovation of biotechnology?

So I certainly commend you for the work that you are doing, and I appreciate your sharing your proposals with us because, as I think you are aware, it is not falling on deaf ears, that there are a number of us that share your enthusiasm for the initiatives that you have articulated, and we hope that we can work in partnership with you.

Thank you for your input.

Dr. BOYER. Thank you.

Mr. WALGREN. If my colleagues will permit, one thing that keeps running through my mind is that in politics and in the political debate we always tend to run down the past. I suppose there is some gain for blaming and holding some near past effort up to describing it as inadequate or wrongful, and yet I am always impressed at how soon we come back, quite quickly, to what was done in the past and near past because those folks weren't so dumb after all and in fact had the best motives to boot.

And my question is if in the '60s we thought a lot about curriculum—this is an area that doesn't change rapidly with human nature—isn't there value there? Are we sort of continually starting at ground zero just because we want to churn the field again, or is there real value out of that earlier attempts to look at curriculum and decide what works and what ought to be taught? Are we really at ground zero?

Dr. BOYER. No, we aren't, and that gives me an occasion, Mr. Chairman, to explain that good work is being done. When I call for larger, more integrative effort, we could turn to many exciting efforts going on today.

I don't think it is inappropriate to say that I think California as a state has been doing some really interesting work and good work to think about what their curriculum K-12 should be and other states as well. You will be hearing from Florida shortly.

We are not starting in a vacuum. We have some heritage here, and we have some state and even local efforts. I am saying, though, that they need to be multiplied and reinforced and where the critical mass should be created.

So I want to make that point very clear.

The other point I wished to make was perhaps to reinforce Mr. Henry's question. I think that a lot of the issues that were raised in the '60s were legitimate and overdue and that we had been neglectful of minorities and women.

The sad fact is, though, that the schools take inordinate responsibility for this; that is, when this nation is in trouble we expect the schools to be Mr. Fix It for the nation. So we almost overburden the schools in terms of what we expect them to do in managing social pathologies, including family pathologies and the like, and in the process it almost overwhelms the day-to-day practitioner in the school who is trying to also accomplish some absolutely essential intellectual objectives.

But I only say I understand what you have said. Some of it was overdue, and the schools really were almost overwhelmed with the social responses they were asked to fulfill.

But back to curriculum, Mr. Chairman, I would say that we have much to learn from the past, and also we have some good examples today.

I would add this, that there is some virtue, however, in rediscovering this every generation or so; that is, a curriculum is not sterile, and half the excitement and value is to rethink what it is we are trying to do. In other words, the process has a value in trying to define it in the new context.

In that regard, let me just add this as a footnote, not to labor this.

I will tell you, I think the way the world is changing, becoming more interdependent, the way in the next century our children are going to have to be thinking about such matters as the ecology and health and food supply, I think that we have to increasingly think of a curriculum that is not only a reflection of the disciplines but integrates those disciplines and then learns to apply them to some of the essential human problems.

So I would like to see the curriculum discussion focus on the next century, not the last, and that is why I think we can learn from the past, look at existing models, but I would like to see us anticipate what our children will need to know in order to live responsibly in the year 2030, and I don't think that kind of creative question has been posed in trying to ask what is the framework of the curriculum for the nation's schools, at least as adequately as it should.

Mr. **Walgren**. Can you comment on NSF's curriculum development over the last five years or so? What is your greatest disappointment in that program?

Dr. **Boyer**. No. I have to say to you honestly that I have not studied the particular models that they fund or the results that have been submitted. So I think it would be unfair to generalize about that. I certainly would if I had taken the time for that, but I have not examined it with care and should not comment.

Mr. **Walgren**. Okay.

Dr. **Boyer**. I was at a meeting at NSF about a month ago, an all day session, in which some of their priorities were discussed, and I was greatly impressed by the new sense of excitement about trying to reinvigorate the schools and direct some of NSF's money toward precollegiate effort and around curriculum and teaching, those principles that I felt were sound, but I hadn't looked at and do not have data regarding the specific projects.

Mr. **Walgren**. How would you balance the effort that NSF might make in science and math education and what should be done through the Department of Education?

Dr. **Boyer**. Yes. My memory of the Department is that they have had very little authorization to engage in science and mathematics; that is, they have not had a history in curriculum, while that has been almost the exclusive prerogative of NSF. So NSF has had the history.

And I think it is also fair to say, Mr. Chairman, that NSF has more status. Over the years it has been identified as more, if I might say so, an elite—I mean that in the best sense—a distinguished enterprise, and that is not to speak disparagingly of the Office of Education or Department, but that grew up in a much more modest fashion, and then as it did expand it turned its resources as a strategy for equity primarily, and as you well know, most of the monies in the Department go toward equality of opportunity, Chapter 1, at the precollegiate and the Pell grants and student loans. You take those two together, you probably have, what, three-fourths of all the funding in the Department.

I would say that is absolutely crucial. In fact, my view is that is the most fundamental national priority, federal government priority, is to work toward equity, and so I don't say that is unimportant. I am saying, however, its efforts have not been around curriculum design generally or around science and mathematics, and they have not had authorizations there and very little discretionary money.

Now, as a footnote, though, it is interesting, my memory is that after Sputnik the funding to Dr. Zacharias and others in trying to redesign physics and curriculum and the like, those came out of certain authorizations in the old Office of Education, not out of NSF. So that was—I am not quite sure what pocket that was, but I think it was an OE-funded effort, quite a bit of that.

But I would say that it would be inappropriate, my bias, to somehow say, well, this now should be redirected under the Department, given NSF's history, its credibility, and so I think it would be wrong for this thing to be caught up in some big jurisdictional debate. I think that would be a turf warfare that we don't need. I would rather see NSF move forward creatively, and if the Department can find ways to implement through authorization, I wouldn't discourage that. But I wouldn't think a big hassle should be made over who is in charge here.

Mr. **Walgren**. Well, let me express our appreciation to you for your being with us this morning, and we look forward to talking with you as a resource in the future.

Dr. **Boyer**. Thanks very much for the time, and I congratulate you again and respect your leadership. Thank you.

Mr. **Walgren**. Thank you kindly.

Let's call then our initial panel—Betty Castor, Dorothy Shao, Ronald Malone, and Mr. Malone is accompanied by Mr. Loeppke.

Why don't we proceed in the order in which I have introduced you to the record, and so we will start with Ms. Castor.

STATEMENT OF MS. BETTY CASTOR, FLORIDA COMMISSIONER OF EDUCATION, TALLAHASSEE, FL

Ms. **Castor**. Mr. Chairman and honorable members of the subcommittee, I am glad to have this opportunity to come before you at a time of unprecedented concern for the achievement of American students in mathematics, science, and related subjects.

This topic has been a high priority for our Department. During the past 18 months, we have developed, along with the Florida Chamber of Commerce, a comprehensive plan to improve math, science, and computer education. Business leaders and educators have worked together to develop more than 100 recommendations toward improving student performance in mathematics and science. Our economic survival depends on it.

I call your attention to the executive summary of this report, which is submitted for the record.

I have been asked today to discuss the problem of the distribution and effective use of new teaching materials for science and math. We should not forget that if we cannot reach the teacher behind the classroom door we will not make the difference that we want to make in education.

Several strategies to change what is taught and how it is taught, however, can have major impact. The impact of textbooks on curriculum can never be underestimated. However, we need to refocus our textbooks so they encourage students to engage personally, to have a hands-on experience with math and science discovery and problem solving.

Learning through application must be a key focus of curriculum reform. We in Florida are working with the Southern Regional Education Board to pilot the development of new courses in principles of technology and applied mathematics through our vocational program. Academic and vocational teachers have joined forces to develop these new high school courses designed to strengthen basic skills through applied learning.

I understand you will hear more about new textbook developments from other panel members.

I think the National Science Foundation's strategy on involving textbook publishers in curriculum reform is a good one. The key to successful implementation of these new and different textbooks, however, will be ensuring their adoption on approved textbook lists in Florida and other large states.

We frequently hear that assessment drives the curriculum. Unfortunately, much assessment in our nation and our state is dominated by minimum standards. It should not be surprising that our students can compete relatively well in mastering basic skills on national and international assessment. What is alarming is that our students cannot compete in either applying these skills or using these skills to solve problems. Yet it is these advanced skills that will be needed in the Informational Age and for our nation's future economic success.

We are working in Florida on this problem. The Council of Chief State School Officers is also looking at new assessment procedures. Modifying curriculum and assessment modes will not produce better students without better teachers.

I cannot over-emphasize the importance of familiarizing teachers with new materials. Teachers have often been an untapped resource in the reform movement. Efforts to enhance teacher preservice and in-service education should be the basic ingredient in the professionalization of teachers, the nationwide movement.

One way teachers can learn about new curriculum is through new technology. We Floridians are proud of the work of Dr. Mary Budd Rowe at the University of Florida and her CDROM project, "Science Helper." The CDROM provides easy access to a thousand lesson plans developed through the National Science Foundation for elementary science instruction.

We are using it in a number of our schools, and teachers are very excited about the limitless possibilities to provide appropriate hands-on lessons.

The expansion and use of CDROMs and other instructional technologies is a high priority of mine that can have a major positive impact on improving education.

I applaud the National Science Foundation for developing such resources and for their current initiatives in developing new elementary curricula. The NSF is right on target.

I am glad that Congress is focusing on putting resources into the education mission of the National Science Foundation budget. I understand that education's share has grown to 10 percent, but I believe that focus should be substantially enhanced to increase the national leadership role.

The education of our young people in math and science is a question of the nation's capacity to compete, and we must have the resources we need for that international competition.

I have some recommendations today for establishing closer working relationships between the National Science Foundation and state policy groups.

First, we need to know what is in the pipeline so we can avoid duplication in our own development efforts. It would also be helpful if we could regularly be informed about projects in the development stage.

Next, communication between state policymakers and the National Science Foundation should be more closely linked. It would be helpful if the Foundation could take a more direct leadership role in assisting states to reform math, science, and computer education.

We would like to be able to turn to the National Science Foundation for assistance in developing pilot efforts for our new initiative.

Next, the Foundation could most appropriately serve as or fund a clearinghouse of information about developments nationwide to improve math, science, and computer education.

In preparing our comprehensive plan, there was no one central place we could go to determine the state of the art. As other states joined the math and science reform movement, a clearinghouse would be a valuable resource center for sharing information and strategies among states.

Finally, teacher education remains a high priority if new curriculum is to be used in our classrooms. In-service programs should encourage the active participation of teachers as partners in redesigning curriculum and refocusing teaching strategies. Preservice programs should pay close attention to developing math and science courses designed specifically for elementary teachers.

Our state has a critical shortage of math and science teachers. Current figures show that we will produce fewer than one-fifth of the mathematics teachers and fewer than 10 percent of the science teachers we need in Florida by the turn of the century.

We must do more to attract good, able young people into the teaching profession.

I am proud that Florida initiated an extensive program of scholarships and loans several years ago. It has had a positive effect.

Since this is one of your areas of interest, I have attached to my written testimony a summary of the various programs now offered to potential teachers in critical shortage fields.

National attention and dollars would be welcomed in providing greater visibility to the critical shortage needs in this area.

Thank you for the opportunity to talk to you about this critical subject.

I am proud that Florida has produced its own comprehensive plan to move ahead. We need the support of the federal government on a variety of important topics—curriculum development, development of teaching materials and resources, enhancement of teacher preparation, funding of incentives for more teachers, and the development of new assessment strategies.

I would be pleased to provide you with a copy of our comprehensive plan once it is completed, and I would be glad to respond to any of your questions.

Thank you.

[The complete prepared statement of Ms. Castor follows:]

Written Testimony Before

U.S. House of Representatives
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

March 9, 1989

by

The Honorable Betty Castor
Commissioner of Education
State of Florida

I am glad to have this opportunity to come before you at a time of unprecedented concern for the achievements of American students in mathematics, science, and related subjects. During the past 18 months, this topic has been a high priority focus for our department, working together with the Florida Chamber of Commerce, to develop a comprehensive plan to improve math, science, and computer education in Florida. Business leaders and educators have worked together to develop over 100 recommendations related to improving student performance in mathematics and science. It is viewed as economic survival; our future depends on it. I call your attention to the executive summary of this report which is submitted for the record.

I have been asked today to review the problem associated with gaining widespread distribution and effective use of new teaching materials for science and mathematics instruction. The diffusion of new ideas and new materials in education is difficult for a number of reasons. Education in this country is based on a long tradition of local control and local decision making by school boards. Where a state can establish required courses, school boards want to reserve the right to select the curriculum that will be used to teach those courses.

Even within school districts there is tremendous variation in how courses are taught. Classroom instruction depends on the experience, teaching style, and preferences of the teacher. Education has been appropriately described as a loosely coupled system -- because of the autonomy of local schools and teachers in determining what is taught and how it is taught. Recent studies of reform by the Rand Corporation (Steady Work, Elmore and McLaughlin) and others have emphasized the importance of the classroom teacher in gaining acceptance of any innovation or reform.

We should never forget that if we cannot reach the teacher behind the classroom door, we will not be making a difference in education.

There are several strategies related to changing what is taught and how it is taught, however, that can have a major impact.

NEW CURRICULUM: The impact of textbooks on curriculum can never be underestimated. However, what is part of the solution, potentially, is currently part of the problem. There have been a number of studies recently that emphasize textbooks' preoccupation with coverage, particularly in math and science--too many topics crammed in to accommodate everybody's interests.

Recent research of eighth grade math books, for example, have documented the redundancy that exists in these books. Less than 50 percent of the material covered is new material. In the first half of the textbook over 70 percent of the material is a rehash of topics already covered.

Studies of science textbooks have reported memorization as being a primary focus. It was called to my attention that one major biology textbook introduced more new vocabulary words than an introductory French textbook at the high school level.

One can only question the appropriateness of these approaches, particularly in light of international comparisons. We need to refocus our textbooks to promote active involvement of students in doing math and science, experimentation, discovery and problem solving. Learning through application needs to be a key focus of curriculum reform. We are working with the Southern Regional Education Board to pilot the development of new courses in Principles of Technology and Applied Mathematics through our vocational program. Academic and vocational teachers have joined forces to develop these new high school courses designed to strengthen basic skills through applied learning.

I understand that we will be hearing more about new textbook developments from my fellow panel members. I think the National Science Foundation's strategy of involving textbook publishers in curriculum reform is a good one. The key to successful implementation of these new and different textbooks, however, will be getting them on the textbook adoption list in Florida and other large states.

ASSESSMENT: We frequently hear that assessment drives the curriculum. Unfortunately, much assessment in our nation and in Florida is preoccupied with minimum standards. It should not be surprising on the international tests that our students can compete relatively well in mastering basic skills. What is alarming is that our students cannot compete in either applying these skills or using these skills to solve problems. Yet, these more advanced skills are what will be needed in the Informational Age and for our country to succeed economically in the future. We are working in Florida on this problem. The Council of Chief State School Officers has been looking at new assessment procedures in this area. There is a tremendous need for developing assessment instruments and new technology, such as simulations, to provide better assessment of the problem solving skills that we are trying to promote in our schools.

TEACHER ENHANCEMENT: As I have already stated, if we cannot impact on the knowledge and teaching methodologies of a classroom teacher, then our efforts will have been in vain. I cannot over emphasize the importance of educating teachers to become familiar with new materials. Teachers, in my opinion, are an untapped resource in the reform movement and efforts to enhance teacher preservice and inservice education should be compatible with the professionalization of teachers movement nation-wide.

We are working with Dr. Ken Tobin at Florida State University, for example, in sponsoring an experimental program in elementary schools to develop mentor teachers to improve instruction in math and science. The results have been impressive; the teachers have been enthusiastic partners in working with their colleagues to make fundamental changes in how math and science is taught. Changing elementary instruction should be a very high priority because international tests show that we are losing the interest of students early.

USING NEW TECHNOLOGY TO PROVIDE ACCESS TO NEW CURRICULUM: We are proud in Florida of the work that has been done by Dr. Mary Budd Rowe at the University of Florida in her CDROM project, "Science Helper." This CDROM provides easy access to a thousand lesson plans that have been developed through the National Science Foundation for elementary science instruction. We are using it in a number of our schools and teachers are very excited about the limitless possibilities to provide appropriate, hands-on lessons. The expansion and use of CDROM's and other instructional technologies is a high priority of mine and can have a major positive impact on improving education.

I would like to applaud the National Science Foundation for developing resources such as this and for their current initiatives in developing new elementary curricular; they are right on target.

I am glad that Congress is putting resources into the education mission of the National Science Foundation budget. I understand that it has grown to 10 percent, but I believe that focus should be substantially enhanced to increase the national leadership role. The education of our young people in math and science is a question of national survival, and we must have the resources that are necessary to wage that new war.

RECOMMENDATIONS FOR AN EXPANDED NSF LEADERSHIP ROLE: I have some recommendations today for establishing closer working relationships between the National Science Foundation and state policy groups:

(1) We need to know what is in the pipeline. We need to have greater access to information about what new curriculum and other assistance we can expect, and when this will be available. We want to avoid duplication in our own development efforts, and it would be helpful if we could, on a regular basis, be informed about projects that are underway.

(2) There needs to be a closer communication linkage with state policymakers. It would be helpful if the National Science

Foundation could take a more direct leadership role in assisting states to reform math, science, and computer education. For example, we have recently developed a comprehensive plan which proposes many new initiatives. We would like to be able to turn to the National Science Foundation for assistance in developing some pilot efforts. Florida, the fourth largest state, together with the support of its business leaders, seeks to become involved in implementing major comprehensive reform initiatives. We need help.

(3) The Foundation could most appropriately serve as, or fund, a clearinghouse of information about developments nationwide to improve math, science, and computer education. This clearinghouse could address the following areas: 1) state policies, 2) new curriculum developed and in the pipeline, 3) assessment developments, 4) textbooks and other instructional materials, 5) technological advances, 6) teacher enhancement initiatives, and 7) innovative projects (what works).

In preparing our comprehensive plan there was no one central place where we could go to determine the state of the art. As other states join the math and science reform movement, this would be a valuable resource center for enabling states to share information and strategies.

(4) Teacher education remains a high priority if new curriculum is to be used in our classrooms. The focus should be on both preservice and inservice programs. Inservice programs should encourage the active participation of teachers as partners in redesigning curriculum and refocusing teaching strategies. Preservice programs need to pay close attention to developing special math and science courses designed specifically for elementary teachers.

Our state has a critical shortage of mathematics and science teachers. Current figures show that we will produce fewer than one-fifth of the mathematics teachers and fewer than 10 percent of the science teachers needed by the turn of the century. It is imperative that we do more to attract good, able, young people into the teaching profession. To this end, I am proud to say Florida initiated an extensive program of scholarships and loans several years ago, which has had a positive effect. Since this is one of your areas of interest, I have attached a summary of the various programs now offered to potential teachers in critical shortage fields. National attention and dollars would be welcomed in providing a greater visibility to the critical needs in this area.

CONCLUSION: Thank you for the opportunity to talk to you about this critical subject. I am proud to report that Florida has produced its own comprehensive plan to move ahead. We need the support of the Federal government on a variety of critical topics--curriculum development, development of teaching materials and resources, enhancement of teacher preparation, funding of incentives for more teachers, and development of new assessment strategies.

I would be pleased to provide you with a copy of our comprehensive plan once it is completed, and I would be glad to respond to your questions.

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A Comprehensive Plan for the Improvement of Mathematics, Science and Computer Education in Florida

Executive Summary

A Joint Project of:
Florida Chamber of Commerce
and
Florida Department of Education
Office of Policy Research and Improvement
1987-1988

MATHEMATICS, SCIENCE AND COMPUTER EDUCATION TASK FORCE

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Ms. Katie Knight
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Mr. Roger O'Brien
Mathematics Supervisor
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President
Florida Association of Math Supervisors
Bartow

Dr. Mary Budd Rowe
Professor of Science Education
University of Florida
President
National Association of Science Teachers
Gainesville

Dr. Ken Tobin
Professor, Science/Math Education
Florida State University
Tallahassee

The development of this *Comprehensive Plan* has been a joint project of the Florida Chamber of Commerce and the Department of Education to make recommendations to improve mathematics, science and computer education.

This plan represents the consensus views of a broadly based group of individuals from the business and education communities. It represents the best thinking of professional educators and researchers in the field. And, it represents the goals and actions we agree are necessary for the State of Florida in the quest to be more competitive in a world economy increasingly dependent upon science and technology.

We defined our mission broadly and ambitiously: to prepare recommendations to make Florida a world leader in mathematics, science and computer education.

The stakes could not be higher. In a world increasingly dependent on the technological skills of its workers and the scientific literacy of its citizens, Florida cannot afford to be second best.

We quickly discovered that educators and business leaders alike share the view that we can — and must — improve our current performance. Business leaders know that far too many young people leave our school system without even the rudimentary skills they need to survive, let alone thrive, in our increasingly technological economy. Business leaders know that corporations will locate new operations where the best-trained labor supply can be found. They know that great improvement is needed if Florida is to retain existing firms and remain attractive to new enterprises.

For their part, educators are acutely aware that some existing programs are not producing the desired results. They know that students do not receive as much meaningful instruction as they should in mathematics and science in the early grades. They know that the best way to interest students in mathematics and science is to make these subjects concrete, real and exciting from the start. And educators know that they need support in providing this kind of "hands-on" learning experience — that their own preparation in mathematics and science requires continued updating and that they must revisit the real world of science and technology to keep up with new ideas and developments.

We challenged ourselves to tackle these big issues — to develop a *Comprehensive Plan* that would focus attention on high-level goals, but would also offer pragmatic suggestions for the accomplishment of the broad objectives.

After fifteen months of meetings, discussions and drafting sessions, we have agreed on more than 100 specific recommendations for bringing Florida schools to the forefront of mathematics, science and the use of computers in education. The proposals contained in this report represent the thoughtful and cooperative work of each and every member of this Task Force. They represent ideas that business leaders and educators from many different points of view agree are essential if our goal for Florida's schools is to be realized.

The need, the direction and the priorities are clear: Florida must take the following immediate steps to assure that its young people have the best opportunities to learn mathematics, science, and the use of computer technology.

- We must assure that mathematics, science and computer education are exciting to our youngest children.
- We must assure that students learn with understanding.
- We must overcome a serious shortage of teachers who are prepared to teach mathematics, science and computer education.
- We must retain our best teachers by assuring that the conditions for their professional growth and development are met.
- We must provide teachers and students with state-of-the-art technology to support and enhance learning.
- We must anticipate future labor-force needs by attracting the best students — especially those who previously have been under-represented at advanced levels -- to mathematics, science and computer education.

- We must invite a wide array of partners to help in meeting the challenge.
- We must take bold but realistic steps to implement this *Comprehensive Plan*.

The members of the Task Force realize that publication of this *Plan* is only the beginning. We have chosen to report candidly and to speak boldly. We invite you to read this report carefully, and to consider the goals and actions that we have decided must be pursued. We invite you at the same time to consider that being world leaders will mean sharing a common understanding of the challenges, a common vision of the future and common strategies for achieving our objectives.

Many partners will have to march together if our goals are to be achieved. New alliances will need to be forged, existing ones strengthened. Indeed, the Task Force itself was a model of the kind of collaborative consensus-building that will be required. It is in this cooperative spirit that we call on all Floridians to join with us in helping to put into place this *Comprehensive Plan* for leadership in mathematics, science and computer education.

Bob Alligood, Chairman Judy Ambler Harry Baum John Bernreuter John Carroll
Cheryl Cliett Tom Denmark Roderick Dickens Mary Ann DuPont Susan Englert
John Geil James Glass Sherrie Glass Julius Hobbs Tom Hopkins Bill Howden
Ron Hutt Preston Jones Pat Kelly Katie Knight Kim Maher Bill Maloy
Nancy McDonald George Mosakowski Roger O'Brien George Rickus
Mary Budd Rowe Kenneth Tobin

EXECUTIVE SUMMARY

FINDINGS

Florida's economic future — and hence the prosperity of *all* its citizens — increasingly will depend on a work force that is technically literate in mathematics, science and computer technology. Unfortunately, there are disturbing gaps between what future Florida workers *should know* and what today's Florida students *are learning*. Fittingly for a report on this subject, much of the story can be told with numbers.

Demand: The Emerging Economy

- Among the qualities required of future Florida workers, none will be more important than flexibility, adaptability and the desire to continue learning. Countless jobs that once required physical strength, manual dexterity and repetitive calculations already require problem-solving abilities and teamwork. These trends appear to be accelerating.

- Nowhere is the need for skilled workers more apparent than in the fast-growing high-technology sector. Florida now has 1,900 high-tech companies employing 150,000 workers — an increase of 244 percent in the past 10 years. If the trend continues, within five years, Florida will rank fourth in high-tech jobs behind California, Texas and Massachusetts.

- Future job growth is expected to be particularly strong for medical assistants, computer systems analysts and operators, health professionals and data processing repair persons — all requiring technical skills. The need for technically skilled employees will be especially acute in the health-care field.

- Even in non-"high-tech" fields, demand for more technical sophistication is needed as the use of computers and related technology expands. Furthermore, the need for technological and scientific literacy extends beyond employer requirements; in an age of the "greenhouse effect", genetic engineering and the like, citizens need some understanding of technological issues to make informed judgments.

Supply: Student Performance and Preparation

- Florida businesses already report shortages of technically skilled workers. In a recent survey, 41 percent of Florida corporations said they had trouble finding qualified professional-technical employees, and one major high-tech firm hires 80 percent of its professional staff from out of state. Without significant changes in the educational system, these shortages are likely to increase.

- Only half of U.S. 17-year-olds have any "sophisticated understanding of mathematics" and a majority of 13-year-olds are "poorly equipped for informed citizenship and productive performance in the workplace, let alone postsecondary studies in science," according to the National Assessment of Educational Progress.

- American students consistently rank near the bottom on international mathematics and science tests. To the extent state data are available, Florida students tend to perform at about the national average.

- On the 1987 State Student Assessment Tests, 26 percent of 5th-graders couldn't solve a purchase problem involving making change from $1; 23 percent of 8th-graders couldn't tell how much time had elapsed between two events given in days, months or years.

- Worse, the performance of U.S. students tends to decrease over time. While U.S. 5th-graders ranked in the middle of science achievement relative to students of 14 other countries, U.S. 9th-graders ranked next to last. Part of the problem is that most high-school students fulfill their mathematics and science requirements by the end of their junior year, and few take advanced courses. Only 14 percent of Florida seniors take physics, for instance, and less than 10 percent of high school students take calculus.

- Achievement levels for minorities and females (who along with immigrants, will make up about 80 percent of Florida's new workers by the year 2000) tend to be lower than for white male students.

- Although Florida has made some progress recently, it appears that we have basically raised scores of students at the lower end of the scale, but have done little to improve performance elsewhere.

- The poor student performance is not surprising. Consider that:

  — The average U.S. elementary student spends only 20 minutes a day on science and 44 minutes on mathematics.

  — Despite studies showing that hands-on, experimental learning is more effective, 84 percent of instruction in secondary school mathematics and science classes and 74 percent in elementary classes is by lecture, a national survey found.

  — Too much mathematics and science education amounts to rote memorization of discrete facts and formulas, with too little attention to the integration of mathematical and scientific principles and processes and not enough emphasis on learning for understanding.

— Too many textbooks are repetitive. One study found that 70 percent of the material in an 8th-grade textbook had been covered in previous grades.

— Despite recent improvements, not enough Florida students and teachers have adequate access to computers and other instructional technology.

Supply: Shortages of Qualified Teachers

- Between 1986 and 2000, Florida is expected to produce only 18 percent of the mathematics teachers and 9.5 percent of the science teachers it needs. Thus, Florida will have to fill these positions by recruiting out-of-staters and non-traditional teachers (such as retired engineers and scientists) — *if* they can find enough qualified candidates.

- Too many teachers are unprepared. In 1987-1988, for instance, about one in ten general-level mathematics and science courses are being taught by teachers not certified in these fields.

- The lack of preparation is especially acute in the lower grades. Elementary education majors averaged less than a single semester hour in mathematics or science during their junior or senior year in college, and none took an upper-division science course.

- Despite recent improvements, Florida teachers remain inadequately compensated, ranking 27th overall nationwide.

- Fifty percent of U.S. mathematics teachers and 60 percent of science teachers say they are unprepared to use computers as an instructional tool, according to a national survey.

GOALS AND RECOMMENDATIONS

The *Comprehensive Plan* advances five basic goals, accompanied by a series of specific recommendations, to improve mathematics, science and computer education in Florida. We conclude with a call to action to all Floridians.

Strengthen the Curriculum

Goal 1: Strengthen the curriculum in mathematics, science and computer education to prepare students for a society demanding a high degree of technological and scientific literacy.

At all grade levels, more conceptual understanding should be encouraged. A curriculum that is an inch deep and a mile wide is inadequate. So is rote memorization of unconnected facts and formulas. Students must understand the relationships between and among mathematical and scientific principles and processes. And they must have a chance to explore a subject in depth, learn to reason scientifically, experiment and test for alternative solutions and reject hypotheses that cannot be supported by the evidence.

Furthermore, it is not just a question of bringing all students up to some universally acceptable minimum level of performance. We must create the opportunity for higher levels of achievement. Specific recommendations include:

- Initiate fundamental curricular reform in elementary school

  — Teach mathematics and science on a daily basis integrating computer technology where appropriate.

  — Expand and integrate topics covered in elementary mathematics and science using an active, problem-solving approach.

  — Build on successful elementary curricula now being used in Florida schools.

  — Give elementary teachers support and assistance in preparing to teach mathematics, science, and computer education.

- Reform middle school curricula

  — Expand new mathematics concepts covered in middle school mathematics to include algebra, geometry, estimation, probability, ratio and proportion, and logic.

  — Ensure science courses include concepts in physical, life and earth/space sciences, and science, technology and society.

  — Emphasize the use of computer technology in all areas of the curriculum.

  — Emphasize "hands-on," problem-centered learning.

- Strengthen secondary curriculum

  — Maintain the high school requirement for three credits in both mathematics and science.

  — Require courses in biological, earth/space and physical science; cover topics in science, technology and society and the history of scientific thought in each course.

  — Redesign the mathematics curriculum to include coverage of topics in probability, statistics, algebra, geometry, trigonometry and calculus.

  — Provide a financial incentive to districts with .2 FTE funding for each student who takes a fourth year of mathematics or science from a specified list of courses.

Provide student incentives such as weighted GPA points for studying fourth year mathematics or science.

- Review all textbooks, software, and instructional materials to assure support for the goals of the *Comprehensive Plan.*

Revitalize Learning

Goal 2: Make mathematics, science and computer education more exciting.

The most effective way to improve academic performance is to make mathematics, science and computer instruction more stimulating. Students should be exposed early and often to the thrill of discovery, to the adventures of observation and to the broader insights into scientific principles that govern their world. Specific recommendations include:

- Expand the real-world application of mathematics and science concepts. Encourage such activities as cooperative education, community-service projects and internships. Expand vocational content in academic courses and academic content in vocational courses.

- Emphasize active experimentation, teamwork, cooperative learning and critical thinking through "spirit of science" approaches. Among top priorities, teachers should devote sufficient time to "hands-on/minds-on" learning through laboratory work, field trips to science museums and similar activities.

- Establish a business/education matching-grant partnership program that provides funds to elementary and middle schools for enhancing the teaching of mathematics and science and the instructional use of computers.

- Provide incentives to restructure schools and school systems to strengthen learning for understanding, and to share successful models and practices.

- Expand summer in-service institutes for elementary and secondary teachers.

- Expand summer school offerings to include advanced as well as remedial mathematics, science, and computer education.

- Resume construction, renovation, and remodeling of laboratory facilities.

- Increase the availability and use of state-of-the-art instructional technology.
  - — Provide students and teachers with greater access to more hardware, appropriate software, phone lines/MODEMs and more networking.
  - — Expand long-distance learning through SUNSTAR.
  - — Use the Model School Consortium to help demonstrate successful uses of instructional technology.

Prepare More Qualified Teachers

Goal 3: Expand the number of qualified mathematics, science and computer teachers.

The success of the *Comprehensive Plan* depends fundamentally on the quality of our teachers. If we want our students to benefit from a more stimulating, demanding and integrated approach to mathematics, science and computer education, we must begin by preparing, recruiting and retaining the best instructors possible. Specific recommendations include:

- Identify and recruit high-quality students to teaching careers through such programs as Future Educators of America.

- Expand existing recruitment, loan and grant programs to recruit and retain qualified teacher candidates.

- Expand efforts to recruit and educate teachers with non-traditional teaching backgrounds, such as retired civilian and military scientists, engineers and technicians.

- Expand the capacity of Florida universities and community colleges to produce one-third of the state's needed mathematics, science and computer education teachers within five years.

- Improve pre- and in-service programs to ensure that elementary teachers are properly prepared to teach mathematics, science and utilize computers in all areas; establish certification standards that require preparation in these fields.

- Continue efforts to improve the compensation (salaries and benefits) of all teachers. And consider special incentives (such as 11 or 12 month contracts) to recruit and retain good teachers in subject areas with critical shortages such as mathematics, science and computer education.

- Create a more professional work environment for teachers. Give teachers more decision-making authority in the schools, more rewards for innovations, and more opportunities to exchange ideas and successful practices.

- Make available expanded professional-development opportunities. Specific suggestions include:

  — Establish an Institute for the Advancement of Teaching for use by teacher teams during the summer.

  — Expand and target summer in-service institutes to update elementary teachers' knowledge and skills in mathematics, science, and the use of computers as a teaching tool.

  — Provide incentives and resources for exemplary teachers to serve as mentor and resource teachers.

  — Expand opportunities for teachers to find summer work in business, industry, government agencies or non-profit institutions through implementation of a new Teacher/Quest program.

Reach Out To Students With Special Needs

Goal 4: Increase motivation, incentives, and opportunities for minority, female, at-risk, disabled and gifted students to pursue programs and careers in mathematics, science and computer education.

Given that 80 percent of Florida's new workers by the year 2000 are projected to be minorities, immigrants and women, and that these groups traditionally have been under-represented in scientific and technical fields, special steps must be taken to encourage their development. The keys appear to be early and sustained interventions to stimulate student interest and boost performance. Specific recommendations include:

- Support exemplary efforts such as magnet programs and centers for academically talented students, develop alternatives to the tracking system, and provide greater access to positive role models.

- Teachers and parents should overcome stereotypes, provide early intervention and counseling, and stress technology-related career opportunities.

- Encourage active participation by parents and communities in mathematics, science, and programs using computer technology to increase participation by under-represented groups.

- Colleges and universities should use the College Reach-Out Program, dual enrollment, advanced placement and financial-aid awards to target under-represented groups for mathematics, science and technical studies.

Get Results

Goal 5: Implement and refine the *Comprehensive Plan* as necessary to make substantial, measurable improvements in mathematics, science and computer education by 1999. And re-examine and adjust statewide and classroom tests, as needed, to support the goals of the *Plan*.

- Implement the *Comprehensive Plan* in three "lighthouse districts" to learn what it will take to succeed statewide.

- Establish a research advisory commission of educators, business executives, scientists, state government officials and others to oversee the *Plan's* evolution and implementation. The commission's top priorities should be to:
  - — Conduct a thorough re-examination of curriculum and assessment goals in all mathematics, science and computer education courses.
  - — Establish and refine measures of success.
  - — Work with the three lighthouse districts and others in implementing the *Comprehensive Plan* and recommend future revisions.
  - — And, working with the Department of Education and the Centers of Excellence in Mathematics, Science and Computer Education, expand the identification, dissemination and implementation of exemplary programs.

- Encourage districts to develop a district plan for implementing the *Comprehensive Plan* in their schools by making them eligible to receive additional funding for mathematics, science, and computer education.

- Initiate further planning at the Postsecondary Education Planning Commission (PEPC) to align programs at community colleges and universities with changes in mathematics, science and computer education in grades K-12.

Classroom and statewide tests accomplish several objectives. They drive curriculum, send a powerful message about priorities, help ensure accountability for results and facilitate the expansion of model programs to other communities. To ensure that tests appropriately measure the goals established by the *Plan*, several steps are necessary:

- Review the statewide assessment program to assure consistency of testing with goals of the *Comprehensive Plan* ; emphasize understanding, application of knowledge, critical thinking, and problem-solving skills.

- Supplement paper-and-pencil tests by developing practical assessment to evaluate such skills as problem-solving, critical thinking, reasoning, cooperative learning, teamwork and the application of knowledge.

- Permit greater use of calculators during tests to ensure that students do not spend a disproportionate amount of time on computational operations.

- Utilize computer sytems for alternative and individualized assessment , analysis, planning, and reporting.

A Final Word

The goal of improving mathematics, science and computer education is not just for teachers, students and policymakers. It is a challenge shared by *all* Floridians: parents, business executives, community leaders and others. We know that our future economic prosperity and societal well-being depends on well-educated people. We know, too, that in an age ever more reliant on technology, effective education must include increased levels of technological and scientific literacy.

The majority of Floridians not directly involved in the educational enterprise nevertheless can make a number of important contributions. Excellent performance begins with great expectations, and the *Comprehensive Plan* has set its sights high. We want our students to be the best — to master difficult subjects, to think creatively, to reason persuasively.

To perform to these high standards, Florida students need the enthusiastic support of the entire community. We have seen time and again how the encouragement of a parent, the enthusiasm of a science museum volunteer, and the personal involvement of a business executive can make a tangible difference in a student's performance. Such mutually reinforcing partnerships should become the rule, not the exception. In this regard, the Task Force makes two recommendations:

- Increase expectations and reward achievement. Having demanded excellence, we also must be sure to reward outstanding achievement. Among the more promising approaches, we encourage communities to reward achievement in mathematics, science and the use of computers as energetically as they now honor athletes, performers and artists.

- Expand the productive collaboration of educators with parents, community resources, business and industry. Programs such as the Education and Industry Coalition of the Florida Chamber of Commerce have played a leadership role in developing new partnerships with industry. Many more such alliances are needed.

Working together, *all* of Florida will benefit from a technically skilled work force and scientifically literate citizenry that can lead the state into a new century of productivity and prosperity.

FLORIDA DEPARTMENT OF EDUCATION
OFFICE OF STUDENT FINANCIAL ASSISTANCE
1988 - 89 AWARD INFORMATION

FINANCIAL AID PROGRAM NAME	APPROPRIATION	# OF ELIGIBLE APPLICANTS	# OF INITIAL AND RENEWAL AWARDS	MAXIMUM ANNUAL AWARD
Teacher Scholarship Loan Program	$2,760,224	726	683	$4,000

A scholarship loan program for upper division and graduate level students who enroll full-time in state approved critical teacher shortage area teacher education programs. The award is repaid through Florida public school teaching service or in cash with interest.

"Chappie" James Most Promising Teacher Scholarship Loan Program	$2,580,000	707	569	$4,000

A scholarship loan program providing one eligible senior from each Florida public school an award of up to $4,000 to become a Florida public school teacher. The award is repaid by teaching service or in cash with interest. For 1988-89 we were able to make more than one award per high school since not all Florida public high school submitted eligible nominees.

Critical Teacher Shortage Tuition Reimbursement Program	$499,410	1020*	1020*	$702

A program which reimburses teachers for the amount of tuition and fees paid for courses taken toward receipt of certification or graduate degrees in critical teacher shortage areas.

*Amounts listed are based on 1987-88 statistics. 1988-89 statistics are not available at this time.

Critical Teacher Shortage Student Loan Forgiveness Program	$451,025	151*	151*	$5,000

A program which repays college loans of teachers who teach in critical teacher shortage subject areas. Statistics listed are for 1987-88. 1988-89 statistics are not available at this time.

FLORIDA DEPARTMENT OF EDUCATION
OFFICE OF STUDENT FINANCIAL ASSISTANCE
1988 - 89 AWARD INFORMATION

FINANCIAL AID PROGRAM NAME	APPROPRIATION	# OF ELIGIBLE APPLICANTS	# OF INITIAL AND RENEWAL AWARDS	MAXIMUM ANNUAL AWARD
Masters' Fellowship Loan Program for Teachers	$250,000	42	28	$6,000 plus tuition and fees for 3 semesters

A fellowship loan program created to attract graduate school applicants into teaching in high priority location area schools (urban and rural low-income area schools). Priority is given to liberal arts and science applicants and applicants making midcareer decisions to enter the teaching profession.

FINANCIAL AID PROGRAM NAME	APPROPRIATION	# OF ELIGIBLE APPLICANTS	# OF INITIAL AND RENEWAL AWARDS	MAXIMUM ANNUAL AWARD
Children of Deceased and Disabled Veterans	$47,755	52	52	Tuition and fees (approx. $1,000)

A scholarship program for dependent children of deceased or 100% disabled Florida veterans or servicemen or servicemen officially classified as "Missing in Action" or Prisoners of War."

PROVIDED 02/27/89

Mr. **Walgren**. Thank you, Ms. Castor.

And we will turn to Mrs. Shao.

STATEMENT OF DOROTHY J. SHAO, EXECUTIVE EDITOR OF SCIENCE, SILVER, BURDETT AND GINN

Mrs. **Shao**. Thank you, Mr. Chairman, members of the committee.

I was invited to provide testimony on one of the NSF-funded programs for developing curricular materials. Silver, Burdett and Ginn and the Houston Museum of Natural Science are recipients of a National Science Foundation grant to develop a new elementary science program, and I was asked to provide more information about that project.

The name of our project is the Science Connection. It is a supplementary program for grades 1 through 6. The program will have a copyright of 1992 and will be available in printed form by the summer and fall of next year.

The goals of the Science Connection project. It is a supplementary program, and our intention is to develop, to field test, and market an elementary science curriculum that students will want to learn and that teachers will be able to teach within their existing teaching skills.

The Science Connection consists of three parts. The basis is what we call a Science Discovery Reader, which has appealing student characters that discover how to solve science problems in the real world, and through this familiar reader format elementary teachers can present science concepts in the context of student experiences.

Another component is the Interdisciplinary Science Connection Workbook, in which student activities blend science content with mathematics, language arts, social studies, and the fine arts.

The unmistakable message here is that science is not an isolated content area, that students and teachers must see science as an integral and interrelated component of what is taught in the elementary grades, and interdisciplinary activities also appeal to children whose strengths are in other learning areas, and finally this approach draws upon the teachers' training in teaching other areas of the elementary curriculum.

The last component are Science Discovery Kits, which utilize very appealing manipulatives in hands-on science activities. Research shows that children learn by doing, and these kits provide science investigations that students can do by themselves or in small groups.

These kits may also focus on adults in science-related careers who do similar activities as a part of their jobs.

So the message for students is clear. If you like these science experiences, you should consider a science career, and both technical and professional science careers are featured.

Funding from the National Science Foundation is available to support the development and extensive field testing required for these new curriculum products. Each component is reviewed by content experts, both in science and in other disciplines addressed by the product. Components are also reviewed for their utilization of appropriate science process skills in problem solving situations.

At each grade level 90 teachers will field test all three components in their classroom, and an additional 50 teachers and educators will review the materials for applicability in the classroom.

This review process is occurring in 10 states, spread geographically across the nation, and the Baylor College of Medicine Research Department is coordinating the evaluation effort.

The Science Connection curriculum will be correct and will work in the classroom before it is marketed.

The Houston Museum of Natural Science, our partner in this project, is coordinating curriculum development. A successful science museum has the expertise needed to develop curriculum materials that students will like and that will relate to science in the real world.

The last partner, Silver, Burdett and Ginn, we are a major publisher of elementary science textbooks, and we have been extremely successful in the elementary science market. Our current Basal Elementary project is one of the best selling in the country.

For example, in the last two years our elementary science program was adopted by over 90 percent of schools in West Virginia, over 70 percent in Florida, and over 90 percent in Indiana.

We have a proven reputation as a leader and promoter of quality science education materials. We bring to this project our experience in developing and marketing education materials for the elementary market, and we are working closely with the Houston Museum of Natural Science to produce a marketable supplementary science program that is directly correlated to most, if not all, elementary science programs.

Our sales force consists of over 150 sales representatives and consultants, who will present the Science Connection program along with our Basal Elementary program to every state in this country, and one proposal under consideration is to provide a sample of the Science Connection program when schools purchase the Basal Elementary Science program.

When a basal program text is purchased, it is a standard practice to provide each teacher with a teacher edition and set of teacher resource materials for every class set of student books. The teacher resource materials provide additional activities and ideas that help teachers customize the teaching of science to meet individual student needs.

So now these teacher resource materials would include a gratis copy of the Interdisciplinary Connection component of the Science Connection. A sample package of the Science Connection will also be developed to distribute to interested customers.

Brochures such as the one I provided and journal ads and commercial workshops at professional science education meetings are other ways that will be used to promote the program.

The Science Connection project has been developed to have the broadest appeal to the non-science trained elementary schoolteacher, and since the majority of the elementary schoolteachers emphasize the teaching of reading, the use of a science based reader will raise the comfort level of teachers and minimize any concerns they may have about the lack of in-service training.

The terms of the NSF grant allow for setting aside a portion of profits for in-service training. This fund will be managed by Silver, Burdett and Ginn, and with the approval of NSF, the company will add its own monies to broaden and enhance the in-service program. Therefore, the more successful the program, the more funds available for in-service training.

In summary, we anticipate no unusual problems in promoting and distributing the program. In fact, because of the in-service funds generated by sales of the program, we expect that the Science Connection will be even more widely used than most programs of this nature.

So we applaud the National Science Foundation for sponsoring this grant, without which programs such as the Science Connection could not be developed. By providing seed money for the research and development of the program and by building in provisions for the funding of in-service programs, NSF has created incentives to the business community for developing, promoting, and improving the teaching of science in this country.

Thank you.

[The complete prepared statement of Mrs. Shao follows:]

To: The U.S. House of Representatives
Committee on Science, Space, and Technology
Subcommittee on Science, Research, and Technology

Statement prepared by: Dorothy J. Shao
Executive Editor of Science
Silver, Burdett & Ginn Inc.
Morristown, New Jersey 07960

THE SCIENCE CONNECTION

A project funded by the National Science Foundation and produced by Silver, Burdett & Ginn Inc. and the Houston Museum of Natural Science.

Project Goals

THE SCIENCE CONNECTION is a three-part supplementary science curriculum (Grades 1-6) with the following goals:

1: To create an interesting student-oriented narrative reader that supplements and expands the science textbook while appealing to the "reading-based" elementary teacher. This component is called *The Science Discovery Reader*.

2: To design a series of related interactive hands-on activities packaged in the most nonthreatening and facilitating way possible. This component is call *The Science Shoebox* Kit.

3: To extend this science curriculum into other content areas and into the community through stimulating activities and projects, each one packaged to appeal to the non-science- oriented student and teacher. These activities are called *The Interdisciplinary Connection*.

Cumulative Goal: To produce a state-of-the-art science curriculum supplement that will give the "science-shy" elementary school teacher innovative materials to extend science teaching beyond the textbook.

Project Scope

Each component of THE SCIENCE CONNECTION has its own interactive approach and strengths and can be used independently of the other two components.

In *The Science Discovery Reader*, concepts are introduced within the context of student experiences, rather than being presented as definitions to be memorized. The informal narratives show science concepts as they are applied and are fun for students to read. Critical thinking questions that ask students to apply their knowledge (thereby showing an understanding of the concepts being taught) are interwoven regularly throughout the narrative text. Stories are carefully composed, considering student reading levels and page-layout guidelines for readers at each grade level. *The Science Discovery Reader* depicts students, and occasionally teachers, utilizing the inquiry approach in problem solving. Student characters serve as role models for the readers. Lesson notes in the Teacher Edition contain practical information to help teachers in their roles as facilitators. An audio tape that dramatizes each story is also provided with *The Science Discovery Reader*.

The Science Shoebox Kits provide teachers with plans and appropriate manipulatives for self-contained, hands-on activities, packaged in shoeboxes or equivalent containers. These kits will make "doing science" convenient and will facilitate individualization. Each Science Shoebox contains objectives, instructions, a materials list, manipulatives, and student activity sheets. An introductory section for teachers provides suggestions for effectively using each Science Shoebox. The Shoebox activities coordinate with the plot and action of stories in *The Science Discovery Reader*.

The Interdisciplinary Connection relates the concepts developed in the textbook series and in *The Science Discovery Reader* to other school disciplines and to the students' out-of-school environment. This component provides the following interdisciplinary product:

1. The Mathematics Connection (mathematics activities keyed to grade level and designed to involve quantification of concepts);
2. The Social Studies Connection (social studies activities involving geography, history, and societal roles);
3. The Language Arts Connection (language arts activities including grammatical constructions and writing skills);
4. The Fine Arts Connection (fine arts activities relating science concepts to art and music); and
5. The Community Connection (multidisciplinary activities involving science in the community). A videotape accompanies this Connection.

THE SCIENCE CONNECTION is an interdisciplinary program. The narrative in *The Science Discovery Reader* is formatted like a reading activity. Its discussion questions are also language arts activities. *The Interdisciplinary Connection* provides mathematics, social studies, fine arts, language arts, and community activities that correlate with each science unit. These interdisciplinary activities are developed at the appropriate academic level. Teachers are encouraged to use the science-related activities to provide a more cohesive academic experience for students. *The Science Shoebox Kits* focus on the process skills that are components of any problem solving curriculum.

Project Impact

THE SCIENCE CONNECTION is designed to change the way teachers and students view the experience of learning science. In many instances, teachers who can verbalize science principles in classroom presentations have difficulty using those principles to explain observable phenomena. THE SCIENCE CONNECTION provides a narrative that shows science concepts and application activities in which students use concepts to explain depicted or described events. This curriculum, with an accompanying answer key, can enhance an elementary teacher's ability to guide an application- level science lesson.

THE SCIENCE CONNECTION will be packaged and marketed by Silver Burdett & Ginn as a supplementary curriculum product, separate from our basal science textbook program. THE SCIENCE CONNECTION does not have the science content component that will allow it to replace the textbook, but it can be used by teachers with other textbooks or with other forms of science reference material. A high correlation among scope and sequences of content exists across the basal elementary science textbook programs that are available for purchase. Teachers can easily cross-reference THE SCIENCE CONNECTION with their specific state or district science objectives and with all textbook programs.

Distribution and Inservice Training of THE SCIENCE CONNECTION

Silver Burdett & Ginn has been extremely successful in the elementary science market. Our current basal elementary program is one of the best-selling programs in the country. Within the last two years, the program was adopted by over 90% of schools in West Virginia, over 70% in Florida, and over 90% in Indiana. We have a proven reputation as a leader and promoter of quality science education materials.

Silver Burdett & Ginn brings to this project our experience in developing and marketing educational materials for the elementary market. We are working closely with The Houston Museum of Natural Science to produce a marketable supplementary science program that is directly correlated to most, if not all, elementary science programs. The sales force, consisting of over 150 sales representatives and consultants, will present THE SCIENCE CONNECTION program along with the our basal elementary program to every state in the country.

One proposal under consideration is to provide a sample of THE SCIENCE CONNECTION program when schools purchase the basal elementary science program. When a basal program text is purchased, a standard practice is to provide each teacher with a Teacher Edition and a set of Teacher Resource materials for every class set of pupil books. The Teacher Resource materials provide additional activities, ideas, and worksheets to help teachers customize the teaching of science to meet individual student needs. These Teacher Resource materials would include a gratis copy of *The Interdisciplinary Connection* component of THE SCIENCE CONNECTION. In this manner, a "slice" of THE SCIENCE CONNECTION program would be received by every user of our basal elementary science program.

A sample package of THE SCIENCE CONNECTION will also be developed to distribute to interested customers. Brochures, such as the one attached, journal ads, and commercial workshops at professional science education meetings are other ways that will be used to promote the program.

THE SCIENCE CONNECTION project has been developed to have the broadest appeal to the non-science-trained elementary school teacher. Since the majority of elementary school teachers emphasize the teaching of reading, the use of a science-based reader will raise the comfort level of teachers and minimize any concerns they may have about the lack of inservice training.

At present, ninety teachers are field-testing the fifth-grade materials. The materials are explained to the teacher, and should it be needed, further clarification can be obtained by calling the field-test site coordinator. The teachers are free to use the materials as they see fit.

Preliminary response shows that teachers have used the materials in a variety of classroom settings with little or no inservice. They report that the materials do indeed work with students and are easy to use and understand. Similar field tests will be conducted for all grades, 1-6.

The results of the field tests will be used to revise the materials to make them even more appealing and usable by teachers and students.

The terms of the NSF grant allow for setting aside a portion of profits for inservice training. This fund will be managed by Silver Burdett & Ginn. With the approval of NSF, the company will add its own monies to broaden and enhance the inservice program.
The more successful the program, the more funds available for inservice training.

In summary, we anticipate no unusual problems in promoting and distributing the program. In fact, because of the inservice funds generated by sales of the program, we expect that THE SCIENCE CONNECTION will be even more widely used than most programs of this nature.

Reports of the poor performance of United States students in math and science have been widely publicized. We applaud the National Science Foundation for sponsoring this grant, without which programs such as THE SCIENCE CONNECTION, could not be developed. By providing seed money for the research and development of the programs and by building in provisions for the funding of inservice programs, NSF has created incentives to the business community for developing, promoting, and improving the teaching of science in this country.

Biographical Sketch of **Dorothy J. Shao**

Mrs. Shao is the Executive Editor of Science at Silver, Burdett & Ginn Inc., a subsidiary of Simon & Schuster Inc. Prior to joining the company five years ago, she worked in the development of science texts at Holt, Rinehart & Winston Inc. She was a middle school science teacher for four years before entering the field of publishing. Mrs. Shao has an Ed.M. degree from Harvard University and a B.S. from Cornell University. She resides in Chatham, New Jersey, with her husband, William, and two children, Julia and Andrew.

Mrs. Shao is responsible for the development of all science product, kindergarten through junior high school from the idea stage through bound book. Silver, Burdett & Ginn Inc. currently publishes a highly successful elementary science program and two junior high programs.

Mr. **Walgren**. Thank you, Mrs. Shao.

We will go on then with Mr. Malone and Mr. Loeppke as well.

STATEMENT OF RONALD R. MALONE, PRESIDENT, KENDALL/HUNT PUBLISHING CO., DUBUQUE, IA; ACCOMPANIED BY LARRY D. LOEPPKE, ASSISTANT VICE PRESIDENT, ELEMENTARY/HIGH SCHOOL DIVISION, KENDALL/HUNT PUBLISHING CO.

Mr. **Loeppke**. Mr. Chairman, Mr. Malone has requested that I make these comments to the committee as the person in charge of the Elementary/High School Division of the company.

Mr. **Walgren**. Fine.

Mr. **Loeppke**. Thank you for the opportunity to speak to you about Kendall/Hunt Publishing Company's efforts to sell and implement science education materials developed with National Science Foundation support.

I am going to focus my comments on our experience with the new high school chemistry textbook, ChemCom, developed by the American Chemical Society with NSF support and published by Kendall/Hunt in January 1988.

You should also know, however, that Kendall/Hunt is the publisher for several other textbooks which have their origins in NSF funding or are currently being funded by NSF in their developmental stages.

Two projects of relevance to this discussion are the science, technology, and society curricula being written for elementary school and middle school by the BSCS in Colorado Springs. These two projects, which we expect to have on the market in 1991 and 1993, will face a market environment similar to the one that ChemCom does today.

Although I am going to mention some barriers to product implementation, we are excited about the market's response to ChemCom so far. We see the signs of positive change in science education, and I would refer you to the article which appears in the current March/April issue of Science Books and Films, the review journal of the American Association for the Advancement of Science, if you are interested in some of our ideas on that further.

The barriers to implementation of a new curriculum like ChemCom fall into two general categories: structural, which has to do with the basic organizational structure of the curriculum in our high schools, and procedural, which has to do with the pedagogical method and style modeled for and used by teachers, the tests used to measure academic success, and the way in which colleges are training new teachers.

From a structural point of view, high schools do not have a ready made curriculum home for a course such as ChemCom. While ChemCom's target audience is the 90 percent of the student population not committed to a career in science, current high school chemistry courses are, by and large, prevocational in nature; that is, they are intended to prepare students for a college chemistry course, which is then intended to prepare students for a career in a science-related field.

Where ChemCom is being successfully implemented, a new course in the curriculum has been created which does not replace, but is an alternative to, the traditional prevocational chemistry. This typically requires that the entire school district administration be involved in the decision to teach ChemCom, and as a result, a very different marketing strategy is required on the part of the publisher.

After one year on the market, I am happy to report to you that more than 400 school districts are using ChemCom and therefore experimenting in some way with this change in their curriculum design. This is not only a result of Kendall/Hunt's sales and marketing efforts but also a direct result of the five-year writing and field testing process coordinated by the American Chemical Society and funded by NSF.

I would mention parenthetically that current NSF funding of the two BSCS projects mentioned previously is for only three years. In order to keep within NSF budget guidelines, BSCS found it necessary to cut back on the length and number of field tests that were originally planned, and this is unfortunate, since both BSCS and Kendall/Hunt believe this will compromise the product in the first edition.

Also from a structural point of view—back to ChemCom—state curriculum guidelines are built on the current prevocational science education model. If a state adoption committee adheres closely to its guidelines, any science textbook that places an emphasis on teaching science in a personally and socially relevant context will be seen as deficient in content. There is only so much time and space in a year-long chemistry course in high school. In fact, the better the evaluation instrument used—take Virginia's, for example—the more of a barrier to the implementation of new science curriculum it is simply because it evaluates the new science material against the old science curriculum.

It is quite clear that in order to provide a relevant context, which learning research shows is the key to long-term memory, some hard choices have to be made about what science facts not to teach. The authors of ChemCom have done this job admirably.

I think most of us would agree that all of our interests would be better served by citizens taking into the voting booth an understanding of chemistry in the environment rather than the remembrance of who first theorized atomic structure.

Now, from a procedural point of view, new science curricula like ChemCom requires a pedagogical style with which the majority of teachers are not comfortable. With ChemCom, and most other Kendall/Hunt science materials, teachers are asked to be facilitators of student inquiry rather than purveyors of truth. A teacher must be able to operate in this kind of cooperative learning environment already or else be taught how to do so.

In response to this challenge, Kendall/Hunt has fostered a network of part-time consultants drawn from those people who originally helped write and test ChemCom, as well as from teachers who have been trained in two-week summer workshops funded by NSF and conducted by the American Chemical Society.

As schools request ChemCom presentations and teacher training from Kendall/Hunt, we fill these requests using this ever-growing network of part-time consultants. In the last year, 1,746 teachers and administrators have attended a Kendall/Hunt-sponsored

ChemCom event, ranging from brief presentations to two-week training sessions in university and school district settings, and this number does not include those that have gone through the NSF-funded and ACS run workshops that they have been doing.

Additionally, what teachers teach in the United States and, therefore, what publishers put in textbooks has become increasingly driven by standardized achievement tests. The anticipated student outcomes from the successful completion of a ChemCom course are not the same as a traditional chemistry course.

As a result, the ACS is now funding the development of an achievement test which appropriately measures student achievement in a ChemCom course. This same test development piece must accompany any curriculum development project which attempts to move in this new direction for science education.

In concluding, I would like to say that at Kendall/Hunt we believe the curriculum development and implementation model pioneered with ChemCom is the best possible route to an improved school curriculum with correspondingly improved support materials. ChemCom has been produced and is being implemented with the combined and coordinated resources of three parties: the National Science Foundation, the American Chemical Society, and the Kendall/Hunt Publishing Company.

The individual best interests of these three parties—the first, to foster the best possible science education for the citizenry of the United States; the second, to promote chemical education and the development of a labor pool of capable chemists; and the third, to produce and sell and implement to as much of the market as possible a profitable educational product—have been combined to yield some very exciting educational change.

Thank you for the time that you have allowed for us to appear before the committee, and I would welcome any of your questions.

[The complete prepared statement of Mr. Loeppke follows:]

COMMENTS TO THE U.S. HOUSE OF REPRESENTATIVES COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY

Larry D. Loeppke
Assistant Vice President
Elementary-High School Division
Kendall/Hunt Publishing Company

Chairman Walgren, Congressman Boehlert, and Members of the Subcommittee on Science, Research, and Technology, thank you for the opportunity to speak to you about Kendall/Hunt Publishing Company's efforts to sell science education materials developed with National Science Foundation support.

I will focus my comments on our experience with the new high school chemistry textbook, **ChemCom**, developed by the American Chemical Society with NSF support and published by Kendall/Hunt in January, 1988. You should also know, however, that Kendall/Hunt is the publisher for several other textbooks which have their origins in NSF funding or are currently being funded by NSF in their developmental stages. Two projects of relevance to this discussion are the science, technology, and society curricula being written for elementary school and middle school by the BSCS (Biological Sciences Curriculum Study) in Colorado Springs. These two projects, which we expect to have on the market in 1991 and 1993, will face a market environment similar to the one that ChemCom does today.

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The barriers to implementation of a new curriculum like ChemCom fall into two general categories: structural (which has to do with the basic organizational structure of the curriculum in our high schools) and procedural (which has to do with the pedagogical method and style modeled for and used by teachers, the tests used to measure academic success, and the way in which colleges are training new teachers).

From a structural point of view, high schools do not have a ready-made "curriculum home" for a course such as ChemCom. While ChemCom's target audience is the ninety percent of the student population not committed to a career in science, current high-school chemistry courses are "pre-vocational" in nature. That is, they are intended to prepare students for a college chemistry course which is then intended to prepare students for a career in a science related field.

Where **ChemCom** is being successfully implemented, a new course in the curriculum has been created which does not replace, but is an alternative to, the traditional pre-vocational chemistry. This typically requires that the entire school district administration be involved in the decision to teach **ChemCom**. As a result, a different marketing strategy is required on the part of the publisher.

After one year on the market, I am happy to report to you that more than 400 school districts are using **ChemCom** and therefore experimenting in some way with this change in their curriculum design. This is not only a result of Kendall/Hunt's sales and marketing efforts, but also a direct result of the five-year writing and field testing process coordinated by the American Chemical Society and funded by NSF.

I would mention parenthetically that current NSF funding of the two BSCS projects mentioned above is for only three years. In order to keep within NSF budget guidelines, BSCS found it necessary to cut back on the length and number of field tests originally planned. This is unfortunate since both BSCS and Kendall/Hunt believe this will compromise the product in its first edition.

Also from a structural point of view, state curriculum guidelines are built on the current pre-vocational science education model. If a state adoption committee adheres closely to their guidelines, any science textbook that places an emphasis on teaching science in a personally and socially relevant context will be seen as deficient in content--there is only so much time and space in a year long chemistry course! In fact, the "better" the evaluation instrument used (take Virginia's, for example), the more of a barrier to the implementation of new science curriculum it is simply because it evaluates the new science material against the old science curriculum.

It is quite clear that in order to provide a relevant context (which learning research shows is the key to long term memory), some hard choices have to be made about what science facts not to teach. The authors of **ChemCom** have done this job admirably. I think most of us would agree that all of our interests would be better served by citizens taking into the voting booth an understanding of chemistry in the environment rather than the remembrance of who first theorized atomic structure.

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In concluding, I would like to say that at Kendall/Hunt we believe the curriculum development and implementation model pioneered with ChemCom is the best possible route to an improved school curriculum with correspondingly improved support materials. ChemCom has been produced and is being implemented with the combined and coordinated resources of three parties: the National Science Foundation, the American Chemical Society, and Kendall/Hunt Publishing Company.

The individual best interests of these three parties--the first, to foster the best possible science education for the citizenry of the United States; the second, to promote chemical education and the development of labor pool of capable chemists; and the third, to produce and sell to as much of the market as possible a profitable educational product--have been combined to yield some exciting educational change.

I thank you for the time you have allowed for us to appear before this committee and would welcome your questions.

Larry D. Loeppke worked for the Institute of Cultural Affairs from 1973 to 1977 in educational and workshop settings in the United States, Canada, Kenya, Nigeria, Hong Kong, and the Phillipine Islands. Since 1977 he has worked with Kendall/Hunt Publishing Company first in the company's College Division as an Associate Editor and Managing Editor, then as National Field Manager and Assistant Vice-President in the company's Elementary-High School Division.

Ronald R. Malone worked in the consumer package goods industry as a district and regional sales manager for the Gillette Company from 1972 to 1979. Since 1979 he has worked with Kendall/Hunt Publishing Company as National Director for Marketing and Sales, Executive Vice-President, and since 1983, as company President.

Kendall/Hunt Publishing Company is part of Wm. C. Brown Group, Dubuque, Iowa. WCB Group is one of the oldest privately held textbook publishers and textbook manufacturers in the United States. Kendall/Hunt is active in both college and elementary-high school textbook markets.

Mr. **Walgren**. Thank you very much for that testimony.

One common thread among the several of you is this importance of in-service training and teacher work with the materials so that they can be used to best advantage and successfully in the classroom.

Can you tell me a little bit about how we might strengthen the presence of that in the system?

Now, NSF is working with that particular materials and apparently encouraged in the Silver, Burdett situation some component of in-service training that was required in the system.

Could you describe that a little bit in detail, Mrs. Shao?

Mrs. **Shao**. One of the terms of the grant is that the proposal when it came from—in this case the Houston Museum of Natural Science—the Houston Museum had to find a sponsoring publisher, and in order for us to make a decision as a company as to whether or not we would support such a proposal, one of the terms of the grant is that we must set aside a proportion of the investment.

NSF contributes money, the publisher contributes a certain portion of money. When this program is published and is sold, a percentage of profits is set aside that must be used exclusively for in-service training, and according to what NSF has told us, since the management of those in-service funds can be handled by us as a publisher—we do this as a regular course. In dealing with our customers, we provide in-service for purchases of our programs. So we know how to do that, and now we have an additional source of funds that we can effectively continue in-service of this new program, and NSF has been very, very clear in telling us that we would be able to control the money as long as we account to them how much actually has been set aside for the funding.

So I think it is an excellent way to promote the teaching of science through in-service training of teachers, which according to everything that we have ever done in our discussion with the customers, in surveys, and so on, that is the greatest need, in-service training. The lack of in-service training is the major problem in science education at the elementary level.

Mr. **Walgren**. Ms. Castor, could we be doing more with in-service training from the national level? Is there something that perhaps we should be thinking about through the NSF to provide greater commitment in that area?

Ms. **Castor**. I don't think there is any doubt about that. I think many of the States, especially in our own State, we have committed large sums of dollars to in-service training of teachers. But this is a shortage area, and oftentimes the in-service funds are directed towards helping teachers acquire the necessary university kind of courses that they need to be certified.

I don't think we have used those dollars broadly enough and directed them towards elementary teachers, who need to get some—in addition to the course work, need some hands-on experience in how to teach young children the fundamentals of science and math, and that is something that the National Science Foundation could do. They could provide models. They could provide training for trainers in the States. It would be very helpful.

Mr. **Walgren**. Can that be done in the context of in-service, or is that not a problem?

As I understand in-service, you are pulling a teacher from his or her paid period of time and——

Ms. **Castor**. Not necessarily. A great deal of that is done in the summer in intensive summer workshops.

Mr. **Walgren**. Is that a sufficient place for it, in the summer workshops?

Ms. **Castor**. Well, it is a good place for it, but we need to direct so much more attention to this entire area. It ought to be done in the preservice program. It ought to be done during the course of the school year, and it ought to be done in summer workshops, and we are going to need to use all of those strategies if we want to become more successful in this area, which we do.

Mr. **Walgren**. Do you know how many of your teachers are reached by NSF-sponsored summer workshops?

Ms. **Castor**. No, I am sorry. I can't answer that.

Mr. **Walgren**. Any idea of a ballpark figure at all?

Ms. **Castor**. No, I am sorry.

Mr. **Walgren**. What role does the State textbook approval process play in enabling these materials to get into the schools?

Ms. **Castor**. Well, in our State they play a major role because school districts must purchase the majority of their materials from a State approved list. Our statutory requirement is at least 50 percent. However, the reality is that the school districts purchase between 85 and 90 percent of their teaching materials—of their textbooks from a State approved list.

So the State does have a major role.

Mr. **Walgren**. How do these new materials break through that? Are they brought through State approval processes without that being a barrier in your experience?

Ms. **Castor**. Well, because of the cost of new textbooks and new materials, most States are on a five or six-year cycle where textbooks are reviewed at six-year intervals. So there is, number one, a problem with that.

Second, they can be offered at that time when the evaluation comes up.

However, school districts still by and large have the flexibility to deal directly with the purchaser, but it has been something that I think more often than not, especially in the large States, has been left to State textbook evaluation committees.

There is a problem with local districts not knowing about the availability of what is out there as far as the development of new materials.

Mr. **Walgren**. Would all the school districts know about the ChemCom course? Has that been brought to their attention somehow by State level officials?

Mr. **Loeppke**. Not in States where the chemistry adoption is not in cycle. In other words, the book has only been out for a year, and various States have different cycles in which they will adopt chemistry.

For instance, in Florida there is not going to be much of the science community, the educational community in science that knows about it simply because it has not been a marketing priority for us because it is not worth spending money there until the State has on its list that it is going to adopt chemistry textbooks.

Mr. **Walgren**. I see.

The gentleman from California, Mr. Brown.

Mr. **Brown**. No questions.

Mr. **Walgren**. Mr. Johnston from Florida.

Mr. **Johnston**. Mr. Chairman, if I could just make a brief observation.

I was fortunate enough to be the President of the Florida Senate when Ms. Castor was the President Pro Tem, the first woman to ever hold that position and the first woman to ever hold a cabinet position in the State of Florida, and a lot of the reforms that we address today were initiated by her when she was in the State Senate, and she is one of the top educators in the country and I am very proud of her.

Ms. **Castor**. Thank you.

Mr. **Walgren**. Well, let me express my admiration. I wish we had had that as background when we started this today. We would have put you before Mr. Boyer. [Laughter.]

Mr. Skaggs. Thank you, Mr. Chairman.

I don't have any questions either, but just a personal comment really directed toward Mrs. Shao, in that Silver, Burdett Company put bread on the table at our home during the '50s and '60s while my father was Art Director there over a long period of time. So I have a great personal affinity for your company and hope you will extend my greetings and that of my father to your colleagues back in Morristown.

Mrs. **Shao**. Happy to do so.

Mr. **Walgren**. Let me ask what it took to get your companies as publishers involved in publishing and trying to distribute these new kinds of materials.

Was the NSF the key to making that happen, or would this happen without the NSF's involvement?

Mr. **Malone**. I will answer that, Mr. Chairman.

Mr. **Walgren**. Yes, Mr. Malone.

Mr. **Malone**. We have a bit of a unique situation. We are a privately held company and have been a college textbook publisher for some 45 years. We from many standpoints wanted to be involved in the elementary/high school publishing arena. So we entered in with some advantages that in my perspective a publicly held company probably would not do. It allowed us to not just look at it as a commercial venture.

We are very proud that we have a true interest—as you have expressed and your colleagues have expressed, we have a true interest in bettering education, and we believe it needs a strong push in that K through 8 area.

I, too, have a daughter that is nine years old, and I heard your first witness this morning say that they had a poll or a survey and the students said they liked math. My daughter—I am proud of her, and she is a very bright young gal—she doesn't like science. The reason science is kind of fit in where it can be fit in. It is a language art approach.

So to get back to the direct approach, we wanted to be involved in better education. To that end, we could look long term. If I had to make one assessment, whether it is your institution here in government or NSF or the publishing industry, it is much too short term thinking. Change takes a long time. Good curriculum takes a long time. Good materials take a long time, and people have not had that focus, in our opinion, especially in the elementary and high school area.

So we chose to get into that, recognizing what we do well. What we don't do as well and should not be doing as well, and that is the development of the content of the book or the curricula. There are people that have far more expertise than us in that area. Thus, we look very hard to align ourselves, to bring our expertise in a cooperative venture with someone of high expertise, such as the American Chemical Society, such as the Biological Sciences Curriculum Study, and others as well.

And, quite frankly, we are involved in Ms. Castor's state in a different discipline, but very, very progressive state, where the state developed their frameworks and curriculum and had mandates in the fitness area, of which we publish the best selling fitness book for the high school area in Florida that followed the exact state mandates. We recognized where the expertise was. We want to publish for the needs that have been developed and described, that the experts say are those needs.

So our approach has been a bit different than perhaps others——

Mr. **WALGREN**. Let me understand a little bit more about how NSF does this.

You are the publisher, but am I understanding that NSF essentially arranges for the development of the content through the American Chemical Society or perhaps through the various resources they can bring to bear? Are they the ones that are substantially funding the development of the content at that point, or are you as publisher? What is the share?

Mr. **MALONE**. My answer to that would be that, no, NSF is not funding—or not doing the development. They are providing monies for those people that I referred to, that have the expertise to write the content within the parameters.

Mr. **WALGREN**. So they are paying for the writing of the content?

Mr. **MALONE**. They are providing monies for the development of that.

Mr. **WALGREN**. And thus far you as a company have not provided monies to write the content yet, and then I guess my question is if they pay for the writing of the content, how is it worked out what they have a right to ask for that?

Obviously, there is a social contribution being made to a private entity.

What did they ask back from you at that point after they paid for the content?

Mrs. **SHAO**. I can answer some of those questions, Mr. Chairman. The NSF is paying for the writing of the content. Our role in this particular project, the Science Connection, is to advise the Houston Museum, and they are very much an educational institution themselves. They have experts that understand children and the teaching of science, and it is our role to advise them to make sure that whatever they develop is going to be marketable and accepted by students and teachers. Our role is to publish this.

NSF has granted the Houston Museum of Natural Science the sum of—I believe it is $1.6 million to write the content, and Silver, Burdett and Ginn in turn is contributing $2.2 million to publish all of these materials.

Mr. **Walgren**. You said that the terms of the NSF grant allowed for the setting aside for in-service monies.

Did it require the setting aside?

Mrs. **Shao**. It requires it, yes. That is a requirement of the grant.

Mr. **Walgren**. How much? What is the proportion?

Mrs. **Shao**. The wording of the grant has been vague, and we have been advised about how best to handle that, and a contract is being developed whereby the Houston Museum of Natural Science, Silver, Burdett and Ginn, and the National Science Foundation will be the signers of this contract, and we are recommending that a portion of profits—we have for most other products—product lines that we have—we set aside a portion of the royalties for that, are set aside and go to authors to reimburse for their role on the project.

In a sense, a percentage of profits like off the royalties will be set aside for in-service. It will probably be equivalent to what authors normally make on a project.

Mr. **Walgren**. I would like to recognize the gentleman from Virginia for any questions.

Mr. **Slaughter**. No questions.

Mr. **Walgren**. And we have been joined by the gentleman from Iowa, Mr. Nagle.

Mr. **Nagle**. No questions, Mr. Chairman.

Mr. **Walgren**. Well, I find it a fascinating area. Let me ask one other question, and I apologize to my colleagues.

Any thoughts on the role of television in the teaching of science at this point in your school systems?

We are of split minds in some ways. Some of us are very enamored of the power of television and ability to replicate and that sort of thing. On the other hand, there is a certain passivity that some people feel is inherent in television that may work against what we are trying to do.

Any comments on TV as you see it in your school systems?

Ms. **Castor**. Well, we have in our state a large system of educational TV. I think it has to be used as a supplemental tool in the teaching of science and math.

We are also developing a satellite network, which I think holds great promise for the delivery of science and math lessons as well.

Mr. **Walgren**. So you are pretty serious about it if you are developing a satellite network?

Ms. **Castor**. Absolutely.

Mr. **Walgren**. What kinds of things would be supplemented? When you say you use it as a supplement, what do you look to it for?

Ms. **Castor**. Well, some basic lessons can certainly be delivered over instructional TV or through our system now of using the satellite network. Then teachers in the classroom have to take that basic lesson that has been delivered and work with it in a hands-on situation with the students.

Mr. **Walgren**. How are we going to develop materials for the television?

Ms. **Castor**. Well, that is the difficulty. That is the problem. We don't have anyone today working on the development of lessons in this area.

Mr. **Walgren**. We would like to ask you some questions in writing, if we could, afterwards, and we want to express our appreciation to you all for coming and being here today.

Ms. **Castor**. Thank you.

Mr. **Walgren**. So thank you very much.

Let me call the next panel—Dr. Jerry Bell, the Department of Chemistry, from Simmons College; Marjorie Bardeen, the Program Director for Friends of Fermilab; and Dr. Paul Saltman, Department of Biology, University of California—San Diego.

Welcome to our process, folks, and we are glad you are here.

Let me invite you to give your testimony in the order in which I just went down the line, and so let's start with Dr. Bell.

STATEMENT OF DR. JERRY A. BELL, PROFESSOR OF CHEMISTRY, DEPARTMENT OF CHEMISTRY, SIMMONS COLLEGE, BOSTON, MA

Dr. **Bell**. Mr. Chairman, members of the subcommittee, besides my role as Professor of Chemistry, I also since 1986 have held the Directorship of the Institute for Chemical Education, which is at the University of Wisconsin.

The Institute was established in 1983, with the aim of revitalizing the teaching of chemistry at all educational levels, and since 1984 we have been fortunate to receive about $5 million in funding from the National Science Foundation.

I am pleased to have this opportunity to present my views on the vital leadership role that NSF must play to continue to reverse the dismal situation we have already heard about.

Mr. Chairman and members of the subcommittee and staff know that I had the privilege of serving as Director of the NSF Division of Teacher Preparation and Enhancement from 1984 to 1986, and I recall with deep appreciation the interest that you, Mr. Walgren, and your colleagues have expressed in science education at NSF. Without the help of this subcommittee and the Congressional committees on appropriation, the NSF budget for science, engineering and mathematics education would still be very small.

I have not yet been able to understand why the Administration is not forthcoming in asking for funds to provide the vital federal leadership role at a level commensurate with the task that faces the nation.

In '81–'82, the Directorate for Science Education was zeroed out. In 1983, the Congress directed NSF to reestablish the science education activities and provided funds. The Foundation dragged its feet, both in terms of putting a staff together and in using the funds appropriated by Congress.

When I came to NSF in 1984, I was quickly engaged in budget and planning activities. At that time numerous reports, including the National Science Board Precollege Commission Report, called on NSF to quickly reestablish its unique role in science and mathematics education.

The NSB report called for an investment of $175 million for precollege programs. Instead of heeding a clear call from this Presidentially appointed body which oversees the Foundation, the Administration asked for a deferral of $31.5 million.

Since 1985, the Administration's requests for science education funding have displayed a dismal lack of leadership and abdication of clearly stated statutory responsibility.

In 1988, the Congress enacted a five-year authorization bill that would double the NSF budget, and the President signed it into law, yet the fiscal 1990 NSF request for the Science Education Directorate is only $190 million, considerably below that which Congress authorized and the President signed into law.

I am wondering whether mathematical illiteracy has reached its highest pinnacle. My mathematics indicates that at the rate of increase now suggested we will fall well short of doubling the SEE budget in five years.

This is an irresponsible budget action that will not help the nation solve its problems.

I want to hasten to point out one thing. These remarks are directed to the top management of the Foundation, the policies which the Director develops with OMB. I have the highest admiration for my colleagues, overworked and underfunded, in the Directorate for Science and Engineering Education.

I continue to hear about the large number of high quality proposals that SEE receives, both in precollege and undergraduate areas, which they cannot support because of insufficient funds.

I continue to hear about the very small SEE staff and about their efforts to get the job done.

Those were normal conditions when I was at the NSF, when the directorate was being reestablished. I am surprised to see that the size of the staff has not increased to match the added fiscal and programmatic responsibilities which SEE has been given by you.

I urge you, Mr. Chairman, and your colleagues to examine and remedy this situation very quickly.

I know I have been invited here today to speak particularly about NSF-funded precollege teacher enhancement projects I have been engaged in, and I shall do so. However, the entire education enterprise from advanced graduate study on up through the primary grades is interconnected, and its leadership at the federal level should be interrelated.

As an example, I understand that the Administration proposes that the Presidential Scholars Program announced by President Bush be housed in the Department of Education. That is a mistake.

I understand that your version of this program, Mr. Walgren, puts this program where it belongs, at the National Science Foundation.

One of my frustrations in working at the Foundation a few years ago was our inability, due to the lack of funding, to develop a comprehensive set of programs that would provide incentives for all levels of the educational system to help solve our problems.

The growth of the science education budget, for which you should take great credit, has enabled SEE to begin developing a broader set of programs. Yet a great deal remains to be done, especially in the area of undergraduate programs, where the initial promise has been frustrated by NSF management decisions that I believe must be changed. I will return to that in a moment.

As far as the precollege teacher programs are concerned, I don't have to rehearse for you the statistics you have already heard about the shortage of qualified teachers or under-prepared students.

NSF has a role. Has the nation the will to do anything about the disastrous situation you have heard about?

In the town I come from we pay a professional baseball player more in one year than any teacher earns in a lifetime or a Congressman earns in a lifetime of service. Where is the leadership that can help turn this around? [Laughter.]

In science and mathematics education leadership must come from the National Science Foundation.

For about a dozen years in the post-Sputnik era NSF funded a substantial program of summer and academic year institutes we all know about. Approximately, $600 million was spent on these institutes, and by some estimates about 50 percent of all eligible teachers participated.

It was a time of great ferment. New curricula, new teaching methods were tried. The morale—and that is the important point—the morale among teachers was very high. There was a sense that someone cared about what they were doing and wanted to help them do it the best possible way.

That someone was the National Science Foundation, exerting its leadership, not dragging its feet.

When NSF funding waned and academic budgets got tight, the institutes disappeared. With the establishment of SEE, again six years ago, there came an opportunity to recapture this vitality that was so apparent during the old institute period and so missing by 1980.

However, the new programs are not simply a rehashing of the good old days. The old institutes were top/down operations. Teacher enhancement projects by contrast are partnerships among teaching colleagues at all levels. Appropriate precollege teachers are involved in all phases of the projects.

For example, the Assistant Director of the Institute for Chemical Education is a high school teacher.

A further change from the past is the emphasis on follow-up activities for and by teacher participants in teacher enhancement projects. The objective is to foster networking among teachers and to encourage teachers to share what they have learned with other teachers.

The teachers teaching teachers model is at the center of the NSF strategy for exerting leadership and multiplying the effect of its limited funds. Such activities were unknown in the old NSF institute projects.

Do these strategies work?

I listen to a lot of teachers say morale is increasing and, based upon ideas from teacher enhancement projects, teachers are reconsidering and reshaping what is taught and how.

Since 1984, for example, about 1,500 teachers have participated in our Institute for Chemical Education two and six-week workshops. Follow-up evaluations show that satisfaction with workshops and their content increases after teachers leave and start to use the material they gained.

Statistically, our average participant carries out the equivalent of a full day workshop for eight to ten other teachers each year. Anecdotally, we know of lots of more sustained activity.

The Woodrow Wilson National Fellowship Foundation has since 1982 administered a series of four-week summer institutes for high school chemistry, mathematics, and physics teachers, which I happen to know something about. To date, about 650 teachers have participated in these workshops, some of whom are in this room.

Since 1984, four-member teams of participants from these workshops have given a series of one-week mini-institutes at several sites around the country. Through last summer 133 of these mini-institutes have been given, with a total enrollment of almost 3,700 teachers. For this coming summer 83 of the mini-institutes will be offered.

One outstanding teacher from this program says it kept him in teaching when he was considering become a full-time General Electric repairman. He and his high school students now work with elementary teachers and do more than 100 elementary school science programs each year in his school district.

Teacher enhancement projects are bearing fruit in a large number of ways. It is too early, however, to assess the effects of teacher enhancement projects on student performance, but it is clear that the more excited and active the teacher, the better the students respond. Within the next five years we will begin to see the effects of NSF leadership on student performance at all levels. It is a long-term process.

We are not out of the woods yet by any manner or mean until some fundamental changes in the nation's priorities occur and education takes its place with defense and baseball. As essential to the well-being of every citizen, the NSF role must be maintained.

The 1983 NSB Precollege Commission recommended an expenditure of $175 million to provide this leadership. An authorization and appropriation of that kind of money today would be just in the nick of time. NSF SEE has a well-formulated plan for allocating this amount among its programs.

Mr. Chairman and members of the subcommittee, I urge you to examine the SEE plan carefully and continue the course you have taken in the past few years toward getting our priorities in order.

At the undergraduate level, undergraduate science, mathematics, and engineering education has been largely overlooked in the educational pipeline for the technological workforce in the U.S. despite its central position in the pipeline.

Further, it plays the most important role in the preparation of the country's future leaders. We have heard about some of those this morning, not only as scientists, but as lawyers, business people, and, yes, the politicians that we heard from.

There have been several recent national reports about undergraduate education as a whole. These reports have raised a number of concerns, including the quality of undergraduate education, over-emphasis and over-specialization, decreased faculty attention to undergraduate programs, courses, and students.

In the remaining couple of minutes, I have two purposes, to urge you to elevate undergraduate education to a coequal level of concern and importance with your appropriate level for precollege education at the National Science Foundation and to urge an approach, consolidation within the National Science Foundation of SEE Directorate of Undergraduate Instructional Programs.

What happened to NSF leadership in undergraduate education?

When you appropriately reestablished the directorate in 1983, there was an oversight. NSF graduate funding, or graduate education activity had never been eliminated in 1981, and you put back precollege activities, but not undergraduate activities because there was no great public outcry as there had been at the precollege level. The result is that we have a pipeline with a gaping hole.

Two years ago there were definite signs that NSF was going to make a major positive move to reassert its leadership and concern for the health of undergraduate education much as it had earlier. Under the leadership of Homer Neal, the National Science Board produced this report, Report on Undergraduate Science, Engineering and Mathematics Education, that called for major initiatives in NSF, and we were at first encouraged with all the rhetoric announcing NSF's plans for undergraduate education.

But closer analysis has turned the hope to disappointment and finally to dismay.

The Neal report called for a strong central management unit within SEE to develop and administer a comprehensive set of programs. Initially, we saw such a unit established, the Division of Undergraduate Science, Engineering and Mathematics Education and a logical, reasonable beginning set of programs was promptly and clearly announced. But now something has gone wrong.

Inexplicably, the SEE undergraduate budget is not being significantly increased, and the Foundation has announced that the majority of undergraduate effort will take place in the research directorates.

These distributed programs are mostly a great mistake. Responsibility for undergraduate programs distributed among the research directorates is diffuse and uneven. With all the good will in the world—and this good will is not always apparent—the research directorates are not organized or staffed to support undergraduate instructional activities.

Not surprisingly, the major thrust in the distributed activities is for the research, not the educational improvement or instructional development called for by virtually all reports on undergraduate education.

NSF needs a strong central unit for undergraduate education that is clearly visible and has adequate resources for the job. SEE's Division of Undergraduate Science, Engineering, and Mathematics Education is the obvious candidate for this leadership role.

A single division provides a focused, responsive point of contact for undergraduate activities of the Foundation.

A single division provides an effective, unified, credible, and attentive voice about undergraduate activities to others parts of NSF and other federal agencies, the states, the colleges and universities.

A single division provides the ability easily to handle broadly disciplinary proposals and interdisciplinary proposals.

I have argued that it is difficult for NSF research directorates to be effective in managing programs designed to help resolve the problems of undergraduate education. Similarly, it would be a serious mistake if NSF efforts to help resolve these problems were vested in an organizational unit that had no ongoing relationship and input from the scientific community with an active interest in research.

Recruiting members of this community as rotating staff in the Division of Undergraduate Education will help avoid this error. Further, there should be strong interaction between the undergraduate division and the research directorates along the lines that I have outlined in my prepared statement.

These suggestions define for the Division of Undergraduate Education a clear leadership role, the primary responsibility and the authority for NSF programs in undergraduate education with a secondary but vital responsibility vested in the research directorates.

The Neal report carefully considered a balanced set of programs. That set is only partially implemented, and in addition, the commitment to double the NSF budget has changed considerably the assumptions in the Neal report that there was going to be no growth in the Foundation.

Thus, conditions have changed somewhat, so that additional efforts should be possible.

The most important programmatic response to the Neal report should be establishing programs which set up a reward structure for faculty who do the most creative work in furthering undergraduate activities in the sciences.

The aim should be to attract good people who work in creative and productive ways over the long term and in ways which will not sap their creativity or their scientific currency.

At present these programs are woefully underfunded and, as my written statement outlines, very unbalanced when compared to the Neal report.

So far I have focused on internal NSF matters related to undergraduate education. Of even greater importance is the manner in which NSF efforts to improve undergraduate education are represented to the universities, colleges, associations, foundations, and others to whom undergraduate education is a significant concern.

Some way must be found to assure that undergraduate programs receive both time and attention from faculty. The NSF leadership role in the community is exerted through the programs it develops and the projects supported by them. To make its leadership credible, it is crucial that the unit responsible for undergraduate education programs at NSF be seen to have undergraduate education in science, engineering, mathematics as its dominant responsibility and priority.

The depth and longevity of problems experienced by undergraduate education argues strongly that we need long-term, sustained commitment to undergraduate education. Past actions of this subcommittee convince me that you, too, recognize this need and are willing to help provide the resources to meet it.

Thank you for this opportunity to bring these concerns to your attention.

[The complete prepared statement of Dr. Bell follows:]

THE NATIONAL SCIENCE FOUNDATION'S LEADERSHIP ROLE IN PRECOLLEGE AND UNDERGRADUATE EDUCATION

Testimony Presented To

U.S. House of Representatives
Committee on Science, Space, and Technology
Subcomittee on Science, Research, and Technology

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and

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Introduction

Mr. Chairman and members of the Subcommittee on Science, Research, and Technology, my name is Jerry A. Bell. I am Professor of Chemistry at Simmons College in Boston, Massachusetts and, since 1986, I have also held an appointment as Visiting Professor at the University of Wisconsin-Madison where I serve as the Director of the Institute for Chemical Education. The Institute for Chemical Education was established in 1983 at the University of Wisconsin with the aim of revitalizing the teaching of chemistry at all educational levels. Since 1984 the Institute has received grants from the National Science Foundation for teacher and other related programming totaling more than $5 million. The Institute continues to develop programs for precollege teachers and, this year, programs for collegiate faculty.

I am pleased to have this opportunity to present my views on the status of science education in the United States and on the all-important leadership role that the National Science Foundation must continue to play to reverse the dismal situation we find ourselves in.

Mr. Chairman, as you and members of this Subcommittee and its staff know, I had the privilege of serving as Director of the NSF Division of Teacher Preparation and Enhancement from 1984 to 1986. I recall with deep appreciation the great interest that you, Mr. Walgren, and your colleagues expressed in NSF's education mission. I assure you that without the help of this Subcommittee and that of the Congressional Committees on Appropriations, the NSF budget for science, engineering, and mathematics education would still be very small. The sum of all the requested increases for the NSF Directorate for Science and Engineering Education since 1986 has been only $54 million. The Nation is grateful for the foresight of the Congress which has provided $120 million in New Obligational Authority to SEE in addition to the new funding which the Administration requested for Fiscal Year 1986.

While at the Foundation (and before and since), I could not understand why the Administration was not forthcoming in asking for funds to provide the vital federal leadership role in science education at a level commensurate with the task which faces the Nation. In 1982 the Directorate for Science Education at NSF was zeroed out; the disestablishment was incomprehensible and a terrible mistake. In 1983, an enlightened Congress directed NSF to reestablish its science education activities and provided funds for that purpose. The Foundation dragged its feet both in terms of putting a staff together and in using the funds appropriated by the Congress and signed into law by the President.

I was recruited to NSF in the summer of 1984 and was quickly submerged into budget and program planning activities. By that time numerous reports, including A Nation at Risk and Educating Americans for the 21st Century, the National Science Board Precollege Commission Report, had called on NSF to quickly reestablish its unique role in science and mathematics education. The National Science Board Report called for an investment of $175 million for precollege programs. Instead of heeding the clear directives of the National Science Board, which is the Presidentially-appointed policy-setting body for the National Science Foundation, the Administration asked for a deferral of funds in the amount of $31.5 million, using all sorts of excuses to justify this action. Since 1985 the Administration's requests for science education funding have displayed a dismal lack of leadership and an abdication of clearly stated statutory responsibility.

Let me explain this point. The NSF Act of 1950 clearly states, "The Foundation is authorized and directed to initiate and support basic research and programs to strengthen scientific research potential and science education programs at all levels." In the post-Sputnik era, NSF lived up to its statutory authority both in research and in education. In the 1980's the support for research grew while the support for education declined.

In 1988 the Congress enacted a 5-year authorization bill that would double the NSF budget and the President signed it into law. Yet, the Fiscal Year 1990 NSF request for SEE is only $190 million -- considerably below what the Congress authorized and the President signed into law. I must tell you that this irresponsible budget request action of the Administration (NSF and, of course, OMB) will not help this Nation solve its problems in science and mathematics education or avert further crises.

I must hasten to make one point very clear. My previous remarks are directed at the top management of the Foundation and the policies which the Director develops with OMB. I have the highest admiration for my colleagues in the Directorate for Science and Engineering Education. They continue to provide excellent national leadership despite limited resources and despite their heavy work overload. I continue to hear about the large number of high quality proposals that SEE receives, in both the precollege and undergraduate areas, which cannot be supported because of insufficient funds. And I continue to hear about the very small SEE staff and about their valiant efforts to get the job done. These were "normal" conditions during the early period of reestablishment, when I was at the Foundation; I am very surprised that the size of the staff has not increased to match the added fiscal and programmatic responsibilities which SEE has been given by the Congress. I urge you, Mr. Chairman, and your colleagues to examine and remedy this situation very quickly.

Mr. Chairman, I know that I have been invited today to speak particularly about the NSF-funded precollege teacher enhancement projects I have been engaged in and I shall do so. However, the entire education enterprise, from the primary grades through advanced graduate study, is interconnected and focussing attention exclusively on one level, or one group of people within it, neglects these important connections. One of my frustrations in working in science education at NSF a few years ago was our inability, due to lack of funding, to develop a comprehensive set of programs that would provide an incentive for all levels of the educational system to help solve the problems the Nation faces. The growth of the science education budget, for which you should take great credit, has enabled SEE to begin developing a broader set of programs, encompassing all educational levels. Yet, a great deal remains to be done, especially in the area of undergraduate programs where the initial promise has been frustrated by NSF management decisions that I believe should be changed.

NSF Precollege Teacher Programs and Outcomes

The Context. I am sure it is unnecessary to rehearse for you, in detail, all of the dismal news we have heard about precollege science and mathematics education. There is a shortage of qualified teachers; many of the teachers now in our classrooms have been inadequately prepared for their task. The present cadre of teachers is fast approaching retirement and there are too few well-prepared young men and women choosing to teach. On national assessments, students show a poor grasp of scientific and mathematical concepts and reasoning skills. Not surprisingly, therefore, the adult populace also exhibits a degree of scientific illiteracy that is shocking and frightening for an advanced technological society that seeks even a competitive, much less a preeminent, position in the modern world. And, on NSF-supported international comparisons, we are disgraced to find that even our best students fall in the lower half when compared to students from several other Western European and Asian countries.

The NSF leadership Role. Has the Nation the will to do anything about this disastrous situation? What does it say about our priorities when a professional baseball player is paid more in one year than a teacher, or a Congressman, is paid for a lifetime of service? Where is the leadership that can help turn things around? In science and mathematics education, leadership must come from the NSF. NSF leadership was certainly envisioned in the NSF Act of 1950, cited above. NSF leadership was at the heart of the NSB Precollege Commission Report that recommended, six years ago, an investment of $175 million in precollege programs. NSF's leadership role was underscored once again in the Congressionally-mandated study of SEE programs and management completed by SRI in 1987. How can NSF exercise this leadership in the area of precollege science and mathematics education?

NSF Teacher Programs. I am here to examine specifically the area of continuing professional development for teachers. For about a dozen years, in the immediate post-Sputnik era, NSF funded a substantial program of Summer and Academic Year Institutes for precollege teachers to up-grade or up-date their content knowledge in science and mathematics. Approximately $600 million was spent on these Institutes; by some estimates, about 50% of all the eligible teachers participated in one or more of these Institutes. Improving the preparation of their teachers played a part in increasing the numbers of well-prepared young men and women choosing careers in science, mathematics, and engineering. But there was much more to the Institutes than these numbers convey. It was a time of great ferment, as new curricula were introduced and new teaching methods tried. The morale among teachers was very high; there was a sense that "someone cared" about what they were doing and wanted to help them do it in the best possible way. The "someone" was the NSF exerting its leadership, valuing teachers, and encouraging the system to do the same.

For all of their excellent qualities, the old Institutes were cut from very conventional academic cloth. They were developed by college and university faculty and focussed almost exclusively on increasing the teachers' store of content knowledge of science and mathematics through special course and laboratory work. This academic model tended to be transferred to the precollege classroom and laboratory, where it is not always appropriate. It works well to prepare able and committed students for technical careers, but is counterproductive to producing a scientifically literate citizenry, or even one that appreciates our enormous present-day dependence on technology.

Since they were "add-ons" to other collegiate programs, when NSF funding waned and academic budgets got tight, the Institutes disappeared. With the establishment of SEE and the creation of the new Teacher Enhancement programs at the NSF six years ago, there came an opportunity to recapture the vitality so apparent during the old Institute period and so missing by 1980. However, informed by both the strengths and weaknesses of the old Institute programs, the new programs are not simply a rehashing of the "good old days." The old Institutes were "top down" operations. Teacher Enhancement projects are, by contrast, partnerships among teaching colleagues at all levels. Appropriate precollege teachers are involved in planning the projects, in writing the funding requests, and as part of the instructional and follow-up activities staff. For example, the Assistant Director of the Institute for Chemical Education is a high school teacher.

Another contrast between the old and new models for continuing professional development activities is that any organization or institution with an educational mission is eligible to seek Teacher Enhancement funds. In addition to colleges and universities, museums, professional societies, school systems, youth organizations, and foundations, among others, are carrying out successful projects. Broadening the eligibility for project development sends a message to the education community that science and mathematics should be made accessible to and understandable by all, not only those headed for technical careers. Non-traditional sources and resources for teacher professional development can help teachers focus on this wider responsibility and ways to cope with it.

A further change from the past is the emphasis on follow-up activities for and by teacher participants in Teacher Enhancement projects. The objective is to foster networking among the teachers (and staff) in order to reinforce what has been done in the more intensive phase of the project, to support introduction of new content and methods the teachers have learned, and to encourage the teachers to share what they have learned with other teachers. This teachers-teaching-teachers model is at the center of the NSF strategy for exerting leadership and multiplying the effect of its limited funds. Such activities were unknown in the old Institute projects.

Outcomes. Do these strategies work? I attend many gatherings of science teachers; almost always, several them will have been to workshops or other presentations by teachers who have been participants in NSF-funded Teacher Enhancement projects, if they themselves have not. Morale is increasing and, based upon ideas from Teacher Enhancement projects they or a colleague have participated in, teachers are reconsidering and reshaping what is taught and how. Since 1984, about 1500 teachers have participated in our NSF-funded Institute for Chemical Education two- and six-week workshops. Follow-up evaluations, by telephone interviews, show that satisfaction with the workshops and their content increases after the teachers leave and start to use their new knowledge and present it to others. Statistically, our average participant carries out the equivalent of a full-day workshop for 8 to 10 other teachers each year. Anecdotally, we know of several participants who have set up school-system-wide continuing workshops for elementary teachers, many others who have applied for and received funding, some from NSF, to do extensive statewide or regional workshops for their peers, others who have developed kits of locally-available materials for teachers to use in their classrooms, and still others who are publishing the results of teaching ideas developed from their participation. These represent substantial multiplier effects.

The Woodrow Wilson National Fellowship Foundation has, since 1982, administered a series of four-week Summer Institutes for high school chemistry, mathematics, and physics teachers. These have been funded by a large variety of sources, including the NSF. I was the Academic Director for the first two years of the chemistry program and have followed it ever since. To date, about 650 teachers have participated. From the beginning, modest funding has been available to the participants to carry out local, state, regional, and national outreach activities. Further, since 1984, four-member teams of participants have given a series of one-week mini-institutes at several sites around the country. Through last summer, 133 of these mini-institutes had been given, with a total enrollment of almost 3700 teachers. For this coming summer, 83 of the mini-institutes will be offered. One of the chemistry teachers who instructs in the mini's used to spend his summers as a house painter to make enough money to support his family. Even though he now makes less money, he says he will never paint another house; the sense of professional pride in serving his colleagues is far too great to give up. Another outstanding teacher from this program says it kept him in teaching when he was considering becoming a full-time General Electric repairman. He and his high school students work with the elementary teachers and do more than 100 elementary school science programs each year in their school district.

Teacher Enhancement projects provide opportunities to keep up to date, to meet colleagues, and to create the networks that are so essential to maintaining the vitality and vigor of the profession, at all levels. They are bearing fruit in the large amount of teacher interaction that is going on, as evidenced by increasing attendance and participation in professional meetings; at the National Science Teachers Association annual meeting next month, more than three dozen presentations and workshops will be given by former participants in the Institute for Chemical Education and Woodrow Wilson National Fellowship Foundation programs. It is too early to assess the effects of Teacher Enhancement projects on student performance, but it is clear that the more excited and active the teacher, the better the students respond. Within the next five years we will begin to see the effects of this NSF leadership on student performance at all levels.

Resources Required. But we are not out of the woods yet, by any means. Until some fundamental change in the Nation's priorities occurs and education takes its place with defense (and baseball) as essential to the well-being and safety of every citizen, the NSF leadership role must be maintained. In 1983, the NSB Precollege Commission recommended an expenditure of $175 million to provide this leadership. An authorization and appropriation of $180 million for precollege programs for Fiscal Year 1990 would be just adequate and just in the nick of time. The SEE Directorate has a well-formulated plan for allocating these funds among its precollege programs, including the Teacher Enhancement programs that directly impact some and indirectly many more teachers. Mr. Chairman and members of the Subcommittee, I urge you to examine the SEE plan carefully and continue the course you have taken in the past few years toward getting our priorities in order.

NSF Undergraduate Science Education Programs

Undergraduate science, mathematics, and engineering education has been the largely overlooked link in the educational pipeline for the technological workforce in the U.S., despite its central position in the pipeline. Further, it plays a most important role in the preparation of the country's future leaders, not only as scientists, but as lawyers, business people, and, yes, politicians. The college years are for most of us the best and last opportunity to opt into science careers, or gain sufficient understanding to vote wisely and live productively in our increasingly technological society.

There have been several recent national reports about undergraduate education as a whole. These reports have raised a number of concerns including: the quality of undergraduate education, over-emphasis on specialization and professionally-oriented programs, and decreased faculty attention to undergraduate programs, courses, and students. Several of the reports express deep concern about the dominance of research interests over undergraduate interests. I hasten to add that what is needed is a sharply increased emphasis and support for undergraduate education, not a decrease in the level of emphasis and support for research. The reports also affirm this view.

My interrelated purposes in the remainder of this statement are twofold:

- to urge you to elevate undergraduate education to a coequal level of concern and importance with your appropriate level for precollege education, and

- to urge an approach, consolidation of NSF undergraduate instructional programs within SEE, that I believe is essential, if the agency is to succeed in long term strengthening of undergraduate education.

The Missing Link. Why has college level science education tended to be overlooked -- indeed "neglected" according to several major studies, inclding the University of California study completed in 1987? The reason is that undergraduate education comes in second on almost everyone's list of concerns.

Consider, first, the scientific community. Their focus is clearly on research and graduate education, the essence of the academic research enterprise. We only need to look at NSF's budget over the years to see that the immediate interests of the research community are, understandably, their own research grants, not the educational system that at some time in the future produces new scientists and enlightened citizens. The Congress, particularly this Committee, has in past years had the foresight to counter (not always successfully) this short-sighted tendency.

Consider, second, the public (and therefore the Congress). After the NSF education programs were abolished in 1981 -- an incredible error -- an enormous and appropriate national concern developed for our elementary and secondary education system. Congress had the wisdom to order reinstatement of the Science and Engineering Education program at NSF, but there was an oversight. NSF graduate education activity was not eliminated in 1981 and in reinstating the SEE program, only precollege activities were returned. Undergraduate activities were overlooked, because there was no great public outcry as there was at the precollege level. Again, undergraduate education was second on everybody's list.

The result is that we have a pipeline with a gaping hole in the middle. NSF typifies and exemplifies this situation nationally. Graduate education continues to be carefully and appropriately attended to by powerful interests. Now precollege education at NSF and, hopefully in the Nation, is beginning to turn the corner, thanks in significant measure to this Committee. But undergraduate education needs serious, long-term attention that parallels the NSF leadership now in precollege education. It's a disgrace that our best high school students compare poorly with students from other countries. But, even more disturbing to me, is the loss of potential science, mathematics, and engineering students in their freshman and sophomore years in college. Precious few American citizens intend to major in science in college. Worse, in their first two years of college, we lose about 40% of that highly selected group who left high school intending to major in science.

Two years ago there were definite signs that NSF was going to make a major positive move to reassert its leadership and concern for the health of undergraduate education, such as it had in the middle 1960's. Under the leadership of Homer Neal, the National Science Board produced the Report on Undergraduate Science, Engineering, and Mathematics Education that called for major initiatives at NSF. Last year we looked with hope as the Division of Undergraduate Education was established within SEE. And we were, at first, encouraged by all the rhetoric announcing NSF's plans for undergraduate education. But closer analysis has turned the hope to disappointment and finally to dismay.

The Cross-Directorate Strategy. The Neal Report called for a strong, central management unit within SEE to develop and administer a comprehensive set of programs. Initially, we saw such a unit established, the Division of Undergraduate Science, Engineering, and Mathematics Education (USEME), and a logical, reasonable beginning set of programs was promptly and clearly announced. In general, the current programs in USEME seem well run, although there have been times when staff is spread too thin, and there is the challenge to retain a tight interdisciplinary group as the staff gets bigger and more diverse. The Division should have a major role in implementing the NSF response to the Neal report in the future. *Establishing USEME was consistent with a beginning NSF response* to the concerns raised in the Neal Report, and, I believe, gave many of us hope that NSF was on track.

But now something has gone awry. Inexplicably, the SEE undergraduate budget is not being significantly increased and the Foundation has announced that the majority of undergraduate effort will take place in the research directorates. This so-called "cross-directorate" strategy is likely to be useful for some research support -- as it was originally intended. However, responsibility for the undergraduate programs distributed among the research directorates is diffuse and uneven; in some cases they seem not to be of high priority. The result for the total undergraduate effort is a disjointed array of claims for activity throughout the NSF, which is confusing, even mysterious, to the national academic community. Not surprisingly, the major thrust in the distributed activities is the support of research, not the educational improvement or instructional development called for by virtually all reports on undergraduate education.

A Strong, Central Focus for Undergraduate Programs. NSF needs a strong, central unit for undergraduate education that is clearly visible and that has adequate resources for the job. SEE's Division of Undergraduate Science, Engineering, and Mathematics Education is the obvious candidate for this leadership role. The concept of distributed management is a failure. The research directorates' primary interest is and always will be the support of research. They are good at that and should continue to do it and be given increased resources for that purpose. They will not and are not giving undergraduate education top priority and the attention it needs. Their distraction with undergraduate education may even be detrimental to their research mission.

What can the single Division do better?

- The single Division provides a focussed, responsive point of contact for undergraduate activities at the Foundation. Undergraduate activities can be focussed only if they are the first priority for those who do them. The Division can be responsive only if has programs and budget authority to do things. It can attract good staff only if they know they will have authority, responsibility, and resources to accomplish something.

- The single Division provides an effective, unified, credible, and attentive voice about undergraduate activities to other parts of NSF and other Federal agencies, the states, and colleges and universities. It is unified because a single group which works closely together can more easily develop unified and consistent policy and practice. Yet, with major disciplines represented in the Division, it can also take into account desirable disciplinary variations. It is credible and attentive because undergraduate activities are its first priority. It can provide a better staff who are more familiar with undergraduate institutions and with undergraduate activities in universities. Research staff are often woefully ignorant of what goes on at the undergraduate level. The undergraduate Division will have more experienced staff because they work on these activities full time.

- The single Division provides the ability easily to handle broadly disciplinary proposals (e.g., chemistry at the introductory level spanning physical, organic, analytical, and macromolecular chemistry) and interdisciplinary proposals. Particularly at the introductory level, almost all work is broadly disciplinary, and some of the most interesting can be interdisciplinary, especially for students not intending a career in the sciences. These are areas that present great difficulty for the research divisions, whose focus is appropriately narrow. An interdisciplinary group which works together and knows whom to talk with in the research divisions, when necessary, is much more appropriate.

I have argued that it is difficult for the NSF research directorates to be effective in managing programs designed to help resolve the problems of undergraduate education in science, mathematics, and engineering. Similarly, it would be a serious mistake if the NSF efforts to help resolve these problems were vested in an organizational unit that had no ongoing relationship and input from the scientific community with an active interest in research. Recruiting members of this community as rotating staff in USEME will help avoid this error. Further, there should be strong interaction between USEME and the research directorates, along the following lines:

- Oversight for NSF programs in undergraduate education should be the responsibility of USEME and include the authority appropriate to meet these responsibilities. USEME should have responsibility for managing undergraduate education programs that do not have a discipline-oriented research thrust. The research directorates should have defined responsibility and authority in the area of undergraduate education; some of this is described in the points that follow.

- The research directorates should have the responsibility for programs that are discipline-oriented research or are an integral part of such research programs. These include programs such as undergraduate research (REU), research in predominantly undergraduate institutions (RUI), and research opportunities for faculty teaching undergraduates (ROA).

- Where research programs include a component for undergraduate education, the program should be managed and funded through the research directorate.

- The research directorates should provide guidance, advice and evaluation of the undergraduate education efforts through an advisory committee of NSF program officers from appropriate directorates for each disciplinary area, participation in the selection of reviewers for proposals received by NSF for undergraduate education, and participation in the review and evaluation of NSF programs in undergraduate education.
- USEME staff should participate in the evaluation of undergraduate programs managed by a research directorate, e.g., the USEME staff should participate in the evaluation of the undergraduate education component of research programs.

These suggestions define for USEME a clear leadership role, the primary responsibility, and the authority for NSF programs in undergraduate education, with a secondary, but vital, responsibility vested in the research directorates. Wherever USEME manages a program, the appropriate research directorate(s) would have an advisory and evaluative role. Conversely, wherever a research directorate manages a program, USEME would have an advisory and evaluative role. In addition, USEME would have the responsibility for oversight and coordination of the total NSF effort in the undergraduate education area.

Undergraduate Programs. The Neal report carefully considered a balanced set of programs. That set is only partially implemented, and, in addition, the commitment to double the NSF budget has changed considerably the assumptions of no growth explicit in the Neal report. Thus, conditions have changed somewhat, so that additional efforts should be possible.

The most important programmatic response to the Neal report is to continue and establish programs which set up a reward structure for faculty who do the most creative work in furthering undergraduate activities in the sciences. The aim should be to attract good people who work in creative and productive ways, over the long term, and in ways which will not sap their creativity or their scientific currency.

In looking at the array of activities considered most important in the Neal report, I am struck by the unbalanced response and the holes which still exist. The instrumentation program is funded but should be broadened to meet a less limited set of needs, particularly at the introductory level. It should be coupled with an aggressive laboratory development program which has been neglected. Curriculum development is now narrowly focussed in calculus and engineering; it should be broadened to include all aspects in all sciences, operated by an interdisciplinary group of people with strong disciplinary identification, and targeted to the most pressing problems as they arise from the community. The program must be structured so that it involves prominent scientists without imposing an unattractive administrative burden on them. These three programs are interrelated, and it is here that the establishment of a reward structure is most likely.

A program in faculty professional enhancement needs to provide more non-research opportunities for faculty. The vast majority of science faculty in the United States do not have research as their primary function, and most of them do not do much research. NSF's response to faculty enhancement has been largely through encouraging research. This is fine for those for whom it is appropriate, but programs must also serve faculty who teach most of the undergraduates. An expansion and extension of the current narrowly-focussed and anemically-funded Faculty Enhancement program is needed.

REU site grants for undergraduate research are roughly adequate and in the spirit of the Neal report. The identification of supplements to standard research grants as a separate activity and counted as an undergraduate program is questionable. They are part of regular research support and have always been so. In any case, they are not part of the Neal report program suggestions.

Programs for minorities are funded somewhat above the level recommended in the Neal report, but it is clear that that even this level is inadequate. Programs, and the level of support, need to be rethought.

There still needs to be a consistent plan for long-range information and data collection, and someone who will devote a substantial amount of time to its design and operation. I know of nothing which has been done here except some vague discussions, although the need identified in the report is just as severe now as when the report was written.

NSF Leadership in Undergraduate Education. The preceding paragraphs have focused on how the USEME office and the research-oriented directorates should interact with one another on undergraduate education programs. Of even greater importance is the manner in which the NSF efforts to improve undergraduate education are represented to the universities, colleges, associations, foundations and other groups to whom undergraduate education in science, engineering, and mathematics is a significant concern. The concerns about undergraduate education across the nation indicate clearly that, on many campuses, the undergraduate enterprise needs much more attention and support than it is now receiving.

Some way must be found to assure that undergraduate programs -- teaching and advising undergraduate students, developing and revising courses, laboratory experiments, and curricula, and presenting the excitement of learning and discovery to undergraduate students -- receive both time and attention from the faculty. Experience indicates this will not happen on campuses with vigorous programs of graduate study and research unless the faculty understand that colleagues as well as departmental and institutional administrations expect this to occur. To convey these expectations and to assure that the understanding does not diminish with time requires that someone, at each of the various levels of administration, consider the undergraduate programs to be of first importance.

The availabilty of funds to support creative work in undergraduate science, engineering, and mathematics education is a powerful incentive to academic administrators. The NSF leadership role is exerted through the programs it develops and the projects supported by them. To make its leadership credible, it is crucial that the unit responsible for undergraduate education programs at NSF (USEME) be seen to have undergraduate education in science, engineering, and mathematics as its dominant responsibility and concern. This is needed if those in the colleges and universities are to understand that undergraduate education at NSF has a priority comparable to that accorded research at NSF. It is also necessary that USEME have the primary responsibility for presentation of the undergraduate education programs to this community, if a clear signal that undergraduate education is important to the NSF is to be given.

The depth and longevity of the problems experienced by undergraduate education in general and in the technical disciplines in particular argue strongly against the view that one-time-only efforts are required. Rather, it is necessary that changes be made in the way undergraduate education is viewed by faculty and their institutions and by those outside who provide the resources and affect the status of undergraduate education. We must recognize that new kinds of long-term commitments to undergraduate education are needed. Past actions of this Subcommittee convince me that you too recognize this kind of need and are willing to provide the resources to meet it.

Thank you for this opportunity to bring these concerns to your attention.

Jerry A. Bell
Curriculum Vitae

Education

A.B. and Ph.D. (Harvard University, 1958 and 1962) in Chemistry.

Research Associateships at Brandeis University in 1961-62, 1973-74, and 1980-81.

Professional Experience

University of California-Riverside, Assistant Professor of Chemistry (1962-67).

Simmons College, Boston, MA, Associate Professor (1967-72) and Professor of Chemistry (1972-present). Chairman of the Department, 1969-73.

California State College, Bakersfield, Visiting Professor and Consultant in chemical education (1974).

Summer Institute for High School Chemistry Teachers, Academic Director (1982, 1983, and 1987) for this program at Princeton, NJ, funded by the Camille and Henry Dreyfus Foundation and the NSF.

National Science Foundation, Science and Engineering Education Directorate, Director (1984-86), Division of Teacher Preparation and Enhancement and, for the last 9 months, Acting Head, Office of Studies and Program Assessment.

Institute for Chemical Education, Program Development Fellow (1983-84) and Director (1986- present). Responsible for overall programs and policies of the Institute, for fund raising, and for reporting on the Institute's progress.

Memberships and Professional Service

American Chemical Society (1965-present). Council member (1975-83); Council Committee on Meetings and Expositions (1975-80); Society Committee on Education (1981-85); Task Force to Study the State of Chemical Education (1982-83); Petroleum Research Fund Advisory Committee (1982-84).

ACS Division of Chemical Education (1965-present). Program Committee (1971-74; Chair, 1973); Secretary/Councilor (1978-83; ex officio member of Executive Committee and Board of Publication of the *Journal of Chemical Education*); Board of Publication (appointed, 1984-86); Chemistry Consultants Service Advisory Board (1983-present; Chair, 1986-present); Division Chair (1988).

ACS Northeastern Section (1967-present). Board of Directors (1975-83); Selection Committee, James Flack Norris Summer Research Scholarships (1978-80; Chairman); Selection Committee James Flack Norris Award in Chemical Education (1981-84; Chairman, 1983).

New England Association of Chemistry Teachers (1967-present).

National Science Teachers Association (1975-present).

Honors and Awards

Manufacturing Chemists Association Catalyst Award to honor outstanding teachers of chemistry (1977).

Visiting Scientist Award, ACS Western Connecticut Section, to honor excellence in chemical education (1979).

John A. Timm Award, New England Association of Chemistry Teachers, in recognition of distinguished contributions to Chemical Education (1986).

Prize for Best Instructional Computer Program, 7th Biennial Conference on Chemical Education (1982).

Mr. **Walgren**. Thank you, Dr. Bell. I appreciate the directness of that testimony, and it is certainly right on the points that we have to respond to.

Ms. Bardeen.

STATEMENT OF MARJORIE G. BARDEEN, PROGRAM DIRECTOR, FRIENDS OF FERMILAB, FERMI NATIONAL ACCELERATOR LABORATORY, BATAVIA, IL

Ms. **Bardeen**. Mr. Chairman, I was asked to come today to share our experiences at Fermilab with teacher institutes.

Before I begin, the teachers that I represent asked that I give you this so that you can see that we are talking about real people.

Mr. **Walgren**. Somebody will bring that up here.

Mrs. **Shao**. See, I used to be a teacher, too.

Quarks and leptons, the Big Bang, the SSC. These topics are an exciting frontier in modern science, one that holds the potential of capturing the interest of young students. Yet few of them have any exposure to today's science before dropping out of the pipeline.

How can our schools provide an experience of science that, one, demonstrates the excitement of science; two, broadens and enriches attitudes; and, three, develops an appreciation for science?

Children need to spend less time memorizing seemingly unrelated facts, formulas, and rules and more time investigating the world around them. They need teachers who are enthusiastic about and deeply involved in the teaching they do.

Sustained efforts are required to give teachers both a more solid background in their subject and better teaching tools.

NSF-sponsored teacher institutes are an essential element of this effort. They work, and in four minutes I am supposed to tell you how.

Institutes work at Fermilab because it is not business as usual. Teachers come to a world class research laboratory for a unique opportunity to witness science being conducted at the frontier of human understanding. Teachers spend four weeks learning with leading research scientists like Leon Lederman, Fermilab Director and 1988 Nobel Laureate in Physics. Equally important, teachers learn how to share this knowledge with their students.

I would like to share with you one of my favorite quotes from one of our participants.

"Do you recall the Toyota commercial"—sorry it is an import car, but maybe the ad is made in America. [Laughter.]

"Do you recall the Toyota commercial where the people yelled 'Oh, What a Feeling! * * *,' as they jumped three feet into the air? That fairly well describes my feelings about my experience of the past month at the summer institute for science teachers Fermilab. I am actually anticipating my return to school this fall where I can try out some of my newly acquired knowledge on my unsuspecting students."

There are some other quotes in the yellow page of my testimony from other teachers.

I believe the NSF teacher institutes have an impact far beyond the programs themselves. They are catalysts that leverage local effort and support. The multiplier effect is demonstrated by continuing activities that develop directly from Fermilab institutes.

Our graduates, armed with new teaching strategies and classroom materials, have organized three local sharing networks for over 500 teachers, who meet monthly during the school year. Our graduates have invigorated professional organizations with new leadership and with exciting hands-on presentations at local, state, and national meetings.

They have organized a countywide annual program for junior high and high school science teachers. They have developed training programs for their colleagues in the elementary and junior high school level, and we expect some 5,000 teachers this year will benefit from these presentations. They are in the process of organizing a regional training program in physics.

Teacher institutes cannot be conducted without federal support. Through Friends of Fermilab, a not-for-profit corporation, the precollege educations at Fermilab receive funds from private foundations and individuals, and school districts do support their participants. However, it has been our experience that the amount of money needed for a significant program like a teacher institute cannot be raised locally on a sustained basis.

All seven institutes at Fermilab were funded in large part by the Office of Energy Research at the Department of Energy and/or NSF, and on the blue sheet in my testimony you can see the percentage of funds that we have been able to get from private and federal sources.

Today most of the best precollege science teachers received advanced training in NSF project science summer courses of the '60s, but now it is time to train a new generation of teachers.

Congress can help schools by providing programs that attract people to teaching and retain them once attracted. Six specific program suggestions are included on page 4 and 5 of my written testimony.

In addition to increased support for NSF teacher programs, legislation could consider increasing funds for precollege science and math education in federal agencies such as the Department of Energy funding regional centers to work with school systems at out-of-school facilities, like national laboratories and museums, and promoting cooperation between NSF and other federal agencies involved in precollege science and math education.

We cannot expect the schools to raise the science literacy of the nation all alone. Many outside partners can and must contribute. We can double and triple our efforts by creating innovative partnerships between the education community and national laboratories, museums, and businesses between formal and informal science programs. With your continued support, schools and teachers can provide exciting science experience.

I would like to thank you for this opportunity to share our experiences at Fermilab and for your past support, and I am happy to invite you to come to Fermilab so you can see what the excitement is all about.

[The complete prepared statement of Ms. Bardeen follows:]

Testimony of Marjorie G. Bardeen
Program Director, Friends of Fermilab
Fermi National Accelerator Laboratory
Committee on Science, Space and Technology
Subcommittee on Science, Research and Technology
9-MAR-89

INTRODUCTION

Quarks, photons, gluons and W's, the Big Bang, the SSC. These high energy physics topics are an exciting frontier in modern science, one that holds the potential of capturing the interest of young students and creating young scientists. Yet, few of our students have any exposure to today's science before they have dropped out of the pipeline. Can we present exciting science classes that demonstrate sound scientific process and present content in line with current scientific knowledge?

Teachers who are uncomfortable or unfamiliar with science teach by the book, and their students memorize seemingly unrelated facts, rules and formulas. Children need to spend less time memorizing and more time investigating the world around them. They need teachers who are enthusiastic and excited about and deeply involved in the teaching they do. Sustained efforts are required to give teachers both a more solid background in their subject and better teaching tools.

NSF sponsored teacher institutes are an essential element of this effort; they work! Institutes work at Fermilab because it is not business as usual. Teachers come to a world class high energy physics research laboratory for a unique opportunity to witness science conducted at the frontier of human understanding. Teachers gain invaluable experience learning for four weeks from leading research scientists like Leon Lederman, Fermilab Director and 1988 Nobel Laureate in Physics. Equally important, teachers learn from their peers how to share this knowledge with their students.

PROGRAM REVIEW

Friends of Fermilab, a not-for-profit corporation that develops and conducts precollege education programs at Fermilab, has received three NSF grants in support of two teacher institute programs, the Summer Institute for Science and Mathematics Teachers and Topics in Modern Physics.

The Summer Institute for Science and Mathematics Teachers (Institute): The overall goal of the Institute is to encourage talented young people to pursue careers in science by improving instruction in the high school classroom. Specific goals include enhancing teachers' backgrounds in basic subject matter, targeting successful and lively teaching strategies and exposing teachers to current developments in research.

Over six years this intensive four-week summer program has given 300 high school biology, chemistry, physics and mathematics teachers an opportunity to enhance their professional competence. Morning lecture programs with Fermilab scientists and university professors strengthen the teachers' backgrounds in basic subject matter and exposes participants to exciting new ways of approaching topics already taught. In plenary sessions eminent scientists present special topics on current scientific research and societal problems related to science. The afternoon laboratory program supervised by master high school teachers is devoted to current methods of computer application in data collection and analysis and to successful teaching techniques for laboratory and problem solving. Sharing successful experiments and demonstrations by the participants is a key part of the laboratory program. Teachers continue their asscciation with Fermilab and stay on track by attending quarterly follow-up sessions during the school year.

Topics in Modern Physics (TMP): The overall goal of TMP is to update high school physics courses by introducing current topics such as the three "supers" - the Superconducting Super Collider, supernovae and superconductivity - into the curriculum. The program enhances the professional competence of secondary physics teachers by demonstrating successful teaching techniques for discussion, laboratory and problem solving, and by strengthening teachers' background in modern physics topics. Prior to the institute, the Topics in Modern Physics Teachers Resource Book (TMP Resource Book) was prepared by six high school teachers and Fermilab physicists. This activity brought together instructional materials from three major Fermilab programs in a format readily usable by the classroom teacher.

This three-week institute for master physics teachers was conducted in the summer of 1988. Twenty teachers were trained as inservice leaders in modern physics topics. Instruction took three forms: background lectures given by Fermilab physicists; presentations and activities from the TMP Resource Book led by high school teachers; and instruction in the preparation and execution of teacher training programs. During the 1988-89 school year the participants are expected to conduct two programs for their colleagues. The twenty-six teachers involved in the program are working together to develop a post-workshop plan for a continuing regional training program for physics teachers. The mainstay of follow-up support comes from three established teacher networks that hold monthly meeting during the school year. In addition, quarterly follow-up meetings are being held during the 1988-89 school year.

When we began, it was not at all clear that a research laboratory was an appropriate setting for major teacher institutes. Teachers have given us the answer, "Yes!" Appendix A includes sample teacher comments. our most important discovery is that a Department of Energy national laboratory like Fermilab can make a significant contribution to the enhancement of science and mathematics education. Second, our experience has shown that although our laboratory is a single purpose institution, teachers from all disciplines can enjoy and benefit from science and mathematics programs held here. In fact, teachers have recognized the advantages of being in an interdisciplinary program. Third, we have shown that teachers respond positively to being treated as professionals and peers by researchers. All were honored to be involved in a program at Fermilab!

MULTIPLIER EFFECT AND PROGRAM IMPACT

It is our experience that NSF teacher institutes have an impact far beyond the programs themselves. They are catalysts that leverage local effort and support. The multiplier effect is demonstrated by activities that develop directly from Fermilab institutes. Our graduates, armed with new teaching strategies and classsroom materials, have organized three local sharing networks for over 500 teachers who meet monthly during the school year; our graduates have invigorated professional organizations with new leadership and exciting hands-on presentations at state, local and national meetings; they have organized a countywide inservice day for junior high and high school science teachers; they have developed inservice programs for their colleagues in elementary and junior high schools - some 5000 teachers will benefit from these presentations in 1989; they are organizing a regional training program in physics. Appendix B includes presentations from and acknowledgements of NSF grant # TEI 8470531 which funded years three, four and five of the Summer Institute.

FUNDING

Teacher institutes cannot be conducted without federal support. Through Friends of Fermilab precollege education programs at Fermilab receive funds from private foundations and individuals. School districts do provide some support for participants. But, it has been our experience that the amount of money needed for a significant program such as a teachers' institute cannot be raised locally on a sustained basis. All seven institutes at Fermilab were funded in large part by the Department of Energy Office of Energy Research and/or NSF. Without the continued support of NSF and the Department of Enegy. Fermilab precollege education programs which have grown from two in FY 80 to some twenty-six in FY 89 would have died. Appendix C reviews the funding of our teacher institutes.

ADDITIONAL COMMENTS

Many of today's best precollege science teachers received advanced training in NSF "project science" summer courses of the 60's. Now, it is necessary to train a new generation of teachers. A variety of programs are needed to support equal and sustained efforts that reach underprepared, average and excellent teachers. The following suggestions for teacher enhancement programs are a summary of recommendations from my colleagues who conduct teacher institutes at other Department of Energy laboratories and from teachers who are staff members for Fermilab institutes. In general, they comment that Congress can help schools by providing programs that attract people to teaching and retain them once attracted. Aggressive funding is needed for elementary school teachers and for school districts with large minority enrollments. Issues of gender fairness and high expectations independent of socio-economic status should be included in NSF sponsored programs.

- Programs to attract teachers should provide scholarships for students planning to teach and offer internships to give them practical experience with activity-based learning and an understanding of how modern science is conducted. Such programs could be sponsored by partnerships between colleges and universities and institutions such as national laboratories and hands-on museums and funded by federal, state and private sources.

- Programs for younger secondary teachers should grant master's degrees in science or mathematics over a period of several summers. This is particularly important if major changes in mathematics curriculum and instruction are to be implemented. Even if new textbooks follow the NCTM standards, extensive training must be provided to current teachers to help them change the methods by which they teach mathematics.
- Programs for more experienced teachers should provide refresher courses where teachers can update their background in their basic subject area and learn new teaching strategies. Research appointments at universities and national laboratories for outstanding teachers are a mechanism not only to reward excellence in teaching but also to keep teachers in touch with science as currently practiced.
- Innovative programs that develop different strategies and may have different expectations should be pursued for underprepared teachers.
- Interdisciplinary science-technology-society programs should be encouraged and should permit support for social science teachers as well as science teachers.
- NSF programs should be funded as long as they remain viable rather than for one two or three years as is the current practice. In order to change curriculum and instruction in a major way, an entire generation of teachers must be exposed to rigourous content and effective instructional techniques. The benefits will be passed on to an entire generation of students.

In addition to increased support for NSF teacher training programs, legislative initiatives could:

- Promote cooperation between NSF and other federal agencies involved in precollege science and mathematics education.
- Increase funds for precollege science and mathematics education in federal agencies such as the Department of Energy.
- Fund regional centers to work with school systems at out-of-school facilities such

as national laboratories and museums.

FINAL REMARKS

We cannot expect the schools to raise the literacy of the nation all alone. Many outside partners can and must contribute. We can double and triple our efforts by creating innovative partnerships between the education community and national laboratories, museums, and businesses, between informal and formal science programs. Your continued support is needed to help us turn kids on to science by tapping the tremendous resources that exist at facilities like Fermilab.

I would like to thank you for this opportunity to speak about Fermilab programs and for your past support. I am happy to invite you to visit the laboratory to see for yourselves what the excitement is all about.

Comments from Participants in Teacher Institutes at Fermilab

"Do you recall the Toyota commercial of the past few years where the people yelled 'Oh, What a Feeling!....' as they jumped three feet into the air? That fairly well describes my feelings about my experience of the past month at the Summer Institute for Science Teachers at Fermilab. I am actually anticipating my return to school this fall where I can try out some of my newly acquired knowledge on my unsuspecting students."

"Before I came to the Institute, I felt I knew most of the answers. As time progressed, I realized just how much had transpired since I was last a student, and at times I didn't even understand the questions. This has been a richly rewarding and stimulating experience for me..."

"My students have noticed my interjections of the work at Fermilab as they now come to me more often asking about Superconductors, Super Colliders, quarks, etc. They enjoy being able to find these topics in the news, whether they read them or hear them."

The SIST (Summer Institute) experience was just wonderful for me! As a'reentering, retraining' teacher it was exactly what I needed." "Programs like this and the support groups which are formed after them are the best things that can happen to science teaching."

"Excitement has been infused into fifteen classrooms and into hundreds of young people studying physics for the first time. These students are getting an exceptional education, after all, they would tell you..."My teacher spent the summer at Fermilab!"

Presentations from and Acknowledgements of NSF Grant

"Science Teachers Gather at Fermilab for Institute," Ferminews, June 27, 1985.

Bardeen, Marjorie, "The 1985 Summer Institute for Science Teachers," Fermilab Report, September, 1985.

Swedler, James, "The Standard Model of Elementary Particles, What Every Science Teacher Should Know," a workshop, Aurora, Illinois, January, February, March, 1986.

Marek, Lee, "Chemistry Demonstrations," at Southeastern Alliance of Chemistry/Physics Teachers, University of Wisconsin, Parkside, WI, January,1986.

"National Laboratories Expand Pre-College Education Programs," Physics Today, p. 103, March, 1986.

Zahrobsky, George, "DOE - National Laboratories Panel Discussion on Pre-College Programs," NSTA Convention, San Francisco, California, March 26-29, 1986.

Jovanovic, Stanka, "1986 Conference on the Teaching of Modern Physics," Fermilab Report, p. 1-8, April-May, 1986.

Marek, Lee, Project SERAPHIM Workshops, Naperville, Illinois, April 25, 1986.

Ladd, Kathy, "Science Institute is a 'Fantastic Experience'," Ferminews, Vol IX, No. 11, July 10, 1986.

Marek, Lee and William West, Presentation of Chemistry Demonstrations from the Summer Institute for Science Teachers at Fermilab, 9th Biennial Conference on Chemical Education, Boseman, Montana, July 27 - August 2, 1986.

Rapinchuk, Peter, "Field Trip Educates Summer Institute Science Teachers," Ferminews, Vol IX, No. 13, August 8, 1986.

Conway, William and Ward Haselhorst, JoAnn Johnson, Jim Ruebush and Walt Schearer, "Modern Physics Topics, Illinois - Iowa Joint Section Meeting of AAPT, Augustana College, Rock Island, Illinois, October 31, 1986.

Ruebush, James and Dr. James Swedler, "Quark Game," Illinois-Iowa AAPT Joint Section Meeting, Augustana College, Rock Island, Illinois, October 31, 1986.

Conway, Bill, "Accelerators," Illinois-Iowa AAPT Joint Section Meeting, Augustana College, Rock Island, Illinois, October 31, 1986.

Johnson, JoAnn, "Cosmology-Age of the Universe", Illinois-Iowa AAPT Joint Section Meeting, Augustana College, Rock Island, Illinois, October 31, 1986.

Schearer, Walt, "Standard Model," Illinois-Iowa AAPT Joint Section Meeting, Augustana College, Rock Island, Illinois, October 31, 1986.

Haselhorst, Ward "Elementary Particles," Illinois-Iowa AAPT Joint Section Meeting, Augustana College, Rock Island, Illinois, October 31, 1986.

Conway, Bill and Ward Haselhorst, JoAnn Johnson, Jim Ruebush & Walt Schearer, "Fermi TMP Group Status Report," 1987 AAPT/APS Winter Meeting, San Francisco, California, January 22, 1987.

Schearer, Walt, "Physics West - A Fermilab Summer Institute Spin-off," NSTA Convention, Washington, D.C., March 26-28, 1987.

Conway, Bill, "Elementary Particles," AAPT PTRA Training Session, Montana State University, Boseman, Montana, June 24, 1987.

Bardeen, Marjorie G., "A Model Program for Introducing Modern Topics Into Introductory Physics Classes", Minicourse on Cosmology, General Relativity & Standard Model, Mexico City, July 17, 1987.

Schearer, Walt, "Elementary Particles," Minicourse on Cosmology, General Relativity & Standard Model, Mexico City, July 17, 1987.

Ruebush, Jim, "Cosmology-Distance Scales," Minicourse on Cosmology, General Relativity & Standard Moder, Mexico City, July 18, 1987.

Jovanovic, Stanka, "Fermilab Sponsors a Mini-Course in Mexico City on the Teaching of Modern Physics," Fermilab Report, pp. 2-6, July - August, 1987.

Ruebush, Jim and Walt Schearer, "Physics Networks," Networks in Physics Education, Oaxtepec, Mexico, July 20, 1987.

Ruebush, Jim and Walt Schearer, "Modern & Not-So-Modern Physics Demos," Northern Illinois University Physics Department Seminar, DeKalb, Illinois, October 2, 1987.

Schearer, Walt, "Modern Physics Topics," Rock Island-Milan Education Conference, Rock Island, Illinois, October 23, 1987.

Jovanovic, Stanka, "Precollege Education Programs at Fermi National Accelerator Laboratory," Fermilab Report, November/December, 1987.

Lederman, Leon M., "Outreach: What a National Laboratory Does About Science Learning," Conference on Informal Learning, Chicago Academy of Sciences, Chicago, Illinois, November 11, 1987.

Ruebush, Jim, "Hubble Expansion," Joint Meeting ISPP/Physic West - Physics NW, Elmhurst College, Elmhurst, Illinois, January 12, 1988.

Johnson, JoAnn, "General Relativity," Joint Meeting-ISPP/Physics West - Physics NW, Elmhurst College, Elmhurst, Illinois, January 12, 1988.

LeMaster, Pat, "Detectors," Joint Meeting, ISPP/Physics West - Physics NW, Elmhurst College, Elmhurst, Illinois, January 12, 1988.

Haselhorst, Ward, "Resistor Symmetry," Joint Meeting-ISPP/Physics West - Physics NW, Elmhurst College, Elmhurst, Illinois, January 12, 1988.

Schearer, Walt, "Square/Triangle Puzzel," Joint Meeting-ISPP/Physics West - Physics NW, Elmhurst College, Elmhurst, Illinois, January 12, 1988.

Conway, Bill, "Accelerators," Joint Meeting-ISPP/Physics West - Physics NW, Elmhurst College, Elmhurst, Illinois, January 12, 1988.

Ruebush, Jim and Walt Schearer, "Topics in Modern Physics Project," 1988 AAPT/APS Winter Meeting, Washington, D.C., January 26, 1988.

Marek, Lee, "Chemistry Demonstrations," 10th Biennial National Chemistry Conference on Education, Purdue, Indiana, February, 1988.

Marek, Lee, "Chemistry Demonstrations," Appleton County Teachers Workshop, Appleton, Wisconsin, February, 1988

LaMaster, Pat, Jim Ruebush and Walt Schearer, "TMP Workshop Plans," DuPage Science Institute, Villa Park, Illinois, March 4, 1988.

Zahrobsky, George, "Video Disc in Science," DuPage County Science Seminar, Willowbrook High School, Villa Park, Illinois, March 4, 1988.

Marek, Lee, "Weird Science" and "How to Start an Alliance Network Group," National Science Teachers Association (NSTA), St. Louis, Missouri, April 7-10, 1988.

Jovanovic, Stanka, "Precollege Programs at DOE National Labs," National Title II Steering Committee, Department of Education, Washington, D.C., April 26, 1988.

Ruebush, Jim and JoAnn Johnson, "Cosmology-Hubble's Law," Chicago Science Teachers Institute-North, Lane Tech High School, Chicago, Illinois, April 30, 1988.

LaMaster, Pat and Drasko Jovanovic, "Demos & Classroom Activities from TMP Book," Seminar on Contemporary Physics, Florida Institute of Technology, Melbourne, Florida, May 6, 1988.

Bardeen, Marjorie G., "Report on Friends of Fermilab Programs," Friends of Fermilab Annual Meeting, Fermilab, May 16, 1988.

LaMaster, Pat and Walt Schearer, "Demos & Classroom Activities from TMP Book," Minicourse for Chicago Public School Teachers - Central, Fermilab, May 21, 1988.

Funding for Teacher Institutes at Fermilab

Summer Institute for Science and Mathematics Teachers

Source	'83 $82,500	'84 $102,650	'85 $122,500	'86 $100,350	'87 $115,150	'88 $204,044
NSF			80%	78%	65%	94%
DOE	61%	51%			12%	
Private	39%	49%	20%	18%	17%	6%
State of Illinois					6%	

Topics in Modern Physics

Source	'88-89 $197,400
NSF	98%
Private	2%

Mr. **Walgren**. Thank you very much. Maybe there is a way we can take you up on that. It would be a very valuable experience.

Ms. **Bardeen**. The plane leaves at 4:00 o'clock this afternoon. [Laughter.]

Mr. **Walgren**. Dr. Saltman.

STATEMENT OF DR. PAUL SALTMAN, PROFESSOR OF BIOLOGY, DEPARTMENT OF BIOLOGY, UNIVERSITY OF CALIFORNIA-SAN DIEGO, LA JOLLA, CA

Dr. **Saltman**. Thank you very much for inviting me here. I did prepare and send to you a written statement, and the more I thought about that statement, the less personal it became and less meaningful I thought it would be to you.

So I am going to take a few minutes—and I mean a few minutes—and first tell you who I am. I am a Professor of Biology. I have been one for 22 years at UC-San Diego, but I must confess to you that I am really a school junkie. I have been in school for 57 years.

It began in the Los Angeles Public Schools, and I wended my way through Cal Tech to a Bachelor's Degree and a doctorate and then spent 14 years on the faculty at the University of Southern California preaching and teaching biochemistry to the medical students and then came to UCSD in 1968—'67, where I served not only as a Professor but as a Provost of one of the colleges and as a Vice Chancellor of Academic Affairs.

I am a scientist. I am a researcher. Over 200 publications, three books. I have grants from the National Science Foundation and the NIH. I am deeply involved at this very minute in what I think are very exciting, wonderful breakthroughs in science.

I am also a teacher. I have always taught large classes of undergraduates and graduates, even when I was a Provost and a Vice Chancellor. I taught because I love to teach. It is very exciting.

I reached out to a national audience by writing a popular course in nutrition. It was a couple of books. We did a course by newspaper that was nationally distributed when I was Vice Chancellor, and I have done many programs for national educational TV because I do believe that all media must be used.

I have served as a Visiting Professor in Paris, in Copenhagen, in Perth, Australia, and in Jerusalem, Israel and in that capacity have seen a lot of different educational systems at work and participated in them.

I am not going to reiterate the crisis we have in mathematics and science literacy. Everyone has told you that and belabored you with it, and I have known it for a long time. I teach the kids who come out of the high schools.

So I thought it was time to stop wringing one's hands and to go do something about it, and one of the things I decided to do about it was to plunge into it.

Having served on the Advisory Board of the Science and Engineering Education Board of the NSF, I asked for a small grant and, with the cooperation of several colleagues, I taught two summer programs, with continuing education through the year, the so-called crossover junior high school and high school teachers.

These are teachers educated in shop, educated in physical education, educated in home economics who suddenly are asked to do biology, chemistry, and physics and their guts tighten up. And I can understand that. So I thought we would do something to help them.

So I brought together a group of our most distinguished faculty from UC-San Diego and, reaching out to the San Diego City and County, did two summer programs of 50 teachers each summer, and it was successful. We did chemistry, physics, biology, and geology for them. Terrific lecturers.

But at the end of the summer and at the end of the year when we had had these continuing programs for them, I was frustrated because there was no continuity. There was no amplification. Furthermore, I kind of felt that it was not reaching into the right level of things to really make change come about in our own community.

So I put together an elementary school program for elementary school teachers to enrich their lives and their science power so that they could come into that classroom and do something, and I am going to talk about that program in terms of its structure and function. Being a biochemist, those two elements of structure and function are absolutely invaluable in understanding mechanisms.

The first thing I have to tell you is the free energy for this program comes in the form of dollars. The National Science Foundation Education Division provided them to us. Without those monies, we could have never gotten those teachers to come and enter our program.

Let me now talk about the structure of the program.

I have nine senior faculty from the UCSD, faculty not only in the School of Medicine and the Scripps Institution of Oceanography but our own program on the general campus as well. We have 21 guest lecturers signed up to do this program. It is carried out, thus, with the top faculty of our institution.

It is carried out under the aegis of the University of California-San Diego Extension Program. Therefore, we have a structure that has to be an institutional structure. I, as a Professor in biology, could never run this program. What they care about in the Department of Biology is what have I published lately. I understand that. Or what do I teach for biology on campus. They don't care about what I do for the elementary school teachers, but we had to have a structure that allowed the function to take place. University extension was ideal.

Then I realized that I don't know anything about elementary school education. I made it through Melrose Elementary School and Third Street, but what do I know about elementary education.

So we went out and we got two absolutely first class, professional pedagogical educators who had spent time in the San Diego City and County School System, two professors, now retired, the doctors' dean.

And at last, but not least, in this structural system was the commitment of the school systems themselves in the City of San Diego and in the county, their commitment to see that if their teachers came in and were provided with the richness and power of this, knowing that they would be provided release time to go out and teach their fellow teachers that which they learned from us and to integrate them within this entire effort.

Okay. So then what is the missing link? The missing link are who are the teachers.

We decided we were going to go for 100 teachers in the City and County of San Diego. We went out and recruited the 100 best, most willing volunteers to come into this program, K through 6.

I will never forget the first day I met with them, and that was this last summer, and it was in July, and I went into this classroom and I asked would you please do me a favor, how many of you have had one year of college science in the course of your credentialing. And I counted the hands. Nine hands went up. Less than 10 percent of those teachers had serious science. Not how do you teach science to elementary school teachers, but really felt empowered with any of the sciences.

So right away there was this fear and loathing of science that I could smell and taste and feel in that classroom that I had to deal with.

But I must tell you something. By the end of that first five weeks—and, by the way, I taught all but two lectures in that first five-week period, five days a week, two and a half hours every morning. I was in that classroom with those faculty, and I will talk more about that later. But the notion was I could see that these teachers became empowered with knowing.

What is the function of this program? How does it work?

Three summers. I told you about the first summer. Modern biology and nutrition, taught to those teachers not in the language of an elementary school student or a teacher, but taught in the language that I would walk in and teach to any major in biology so that they felt that they knew the same biology that any person going on into biology would know or go on into nutrition would know. Nothing watered down. Nothing—no, you know, thin gruel. It was heavy stuff.

So in the morning they were taught the formal lectures, and in the afternoon then they would be given the opportunity to break off into groups, K through 2 and then 3 and 4 and 5 and 6, and all of that information that we had imparted, all of the visual material that we had presented them, all of the use of the college level textbooks that they were told to learn, because I am—you know, I am kind of like the godfather. When a kid comes into my class—and I don't care whether it is a K through 6 teacher or a freshman—a deal goes down. They are going to learn the material, and I am going to teach the material, and it works every time, providing everyone understands that that was the deal, and the deal was they were going to learn biology and nutrition, and they did.

And then they did that important step in the afternoon, working with science professionals at the elementary level. They took that material into laboratories at UCSD and translated it into projects, experiments, curricular developments, use of textbooks, integration with the California science guidelines, so that that which they had in the morning became a reality for their classroom that afternoon or soon after.

That is the program that we ran this last summer. Next summer will be geology, oceanography, meteorology, and astronomy. The summer after that is going to be the chemistry and physics of everyday life.

Those teachers are empowered now. Every month they come back onto campus. I give them the most intense and wonderful faculty to speak to them. Last Saturday Marty Chrisfields, one of the great plant molecular biologists, lectured to them about gene jockeying in plants in the future, and these teachers understood it. He didn't give a watered down, mushy seminar. He gave them hard core stuff, and they ate it up. It was beautiful.

It develops in this structural relationship a network among these teachers. Those 100 teachers have a brotherhood and a sisterhood the likes of which I think is rare that I have seen among the public school teachers in our community, and they have also developed the network so that they feel comfortable with me and the other faculty members with whom they interact.

I get telephone calls day and night. They have my home phone. They have my office phone. They call me. Hey, a kid asked me a problem about this. Who do I go see? Boom, it is theirs.

They are empowered. They don't have to be frightened any longer.

Then the question was asked, you know, well, is it working, is there any amplification of this thing?

We have a deal that is part of the Mafia contract of them signing on. Every one of you is committed to teach a minimum of ten of your fellow teachers in your school or in your district or you are out of here. That program is already in place, and I can tell you at the present time, at the last count we made, 693 teachers are being taught, and that is only by a handful of about ten of our best faculty, and the rest are going into that program the coming summer to do it.

The amplification is working. I feel very good about that. I am not frustrated anymore.

You say does it help the teachers; how do you know that? I keep getting questions that were sent to me by your committee. How do you know they know anything?

We test them at T-zero. We tested them at the end of five weeks. I would love to show you their exams.

Can you imagine third grade teachers who didn't even know there was a science of thermodynamics can explain the first and second laws now in languages that I can understand and their kids can understand? They understand about how DNA begets RNA begets protein, and they can talk about it and do experiments about it.

That is in the examination. That is in the knowledge that they have acquired.

They have developed new curriculum. I have seen it. I have been in the schools. The deans go into their schoolrooms every day to monitor the progress, to serve as resource people.

It is working.

One of the teachers—we did a questionnaire. We said, how much time do you spend teaching science per week in your classroom? You know, the high numbers were 20 minutes. And you know what they are saying now? Every day I teach 15, 20 minutes of science. I bring in the morning newspaper. We talk about public events and how it relates to science and what is the science meaning of these various activities of the ozone layer, of splicing genes, of cancer, of AIDS, whatever it is. Those teachers now feel they can walk in and do kind of a Mort Sahl number out of the morning paper and bring the science in with the laughter.

That is not trivial.

We have monitored the in-service training. We are on top of it all the time, and I got to tell you another piece of it, which is kind of wild, and that is the faculty that I had to cash in my markers to get to come into this program because my faculty colleagues don't do this for money. They do it because I break their arm, and I said, you know, come on, you got to do this, it is God's will, you got to teach these teachers, and they kind of looked at me like I was crazy, but that is certifiably true.

But what happened to those faculty on our faculty are wonderful. They fell in love with those teachers. They have continued their relationship with those teachers on an ongoing basis, have gone from the university into the classrooms of the teachers, have brought classrooms of first, second, third, fourth, fifth, sixth grade kids into their own laboratories to show them. That is an act of love. Nobody pays them to do this, and certainly the academic senate doesn't reward it in promotions.

An epilogue. I got to tell you something, true confessions. This has been the most passionate and joyous teaching that I have had the pleasure of doing. I have done a lot of teaching. I have won a lot of awards for teaching. This has been really a remarkable, emotional experience for me.

And as I say that, I say to you also it is only through the NSF that this program could have come about. I don't know anyone else who is doing this, who would have funded it, would have allowed this kind of a powerful academic institution to interact with the school system and those teachers to make good things happen.

People have talked a lot about curricular development in TV and this and that. Mr. Chairman, it is the strength and the power and the knowledge of the teacher in the classroom that makes the difference in the learning experience. You can have all of the great textbooks in the world, and if you don't have a teacher as a catalytic agent to make that change come about, who feels a sense of comfort with that science, science and math education will never come about.

And we cannot wait for Godot. I feel like I am living in a Beckett play. I am going crazy waiting for Godot, and the only way I cannot wait any longer is to not wait for the training of the future teachers. We have men and women in our classrooms now. We must empower them with knowledge. That is where the catalytic process begins. That is where enormous efforts must be taken.

I think that your committee is so important in the sense that the appropriations that you give to the NSF to carry through these programs, not only on the precollegiate levels but in the collegiate levels as well, which I deeply appreciate because I am a part of that enterprise. That is my life's blood. Protect it and extend it.

And the other thing I would say to you is that I think that the NSF really deserves the full support of the Congress for both education and research. I think teaching and learning are the yen and yang. They cannot be separated.

Thank you.

[The complete prepared statement of Dr. Saltman follows:]

STATEMENT OF DR. PAUL SALTMAN, DEPARTMENT OF BIOLOGY, UNIVERSITY OF CALIFORNIA - SAN DIEGO BEFORE SUBCOMMITTEE ON SCIENCE RESEARCH AND TECHNOLOGY, HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY, WASHINGTON, D.C., MARCH 9, 1989

Members of the Research and Technology Subcommittee:

I am Paul Saltman, a Professor of Biology at the University of California - San Diego. I come before you today to lay out my views on the state of science and engineering education in the United States and to offer some suggestions for improving its quality.

Study after study over the past decade or so has confirmed the worst fears of many educators and scientists. We are in a crisis that requires prompt and effective action. I do not need to elaborate for this subcommittee the results of recent surveys that rank American pre-college students far below their contemporaries in other countries in their understanding of the natural sciences and mathematics. There is a general turning away, on the part of young people, from careers in those fields of learning.

By the year 2000, nearly half a million jobs requiring bachelor of science degrees will be unfilled for want of qualified candidates. The young men and women who should be receiving those degrees at commencement exercises just 11 years from now are already in the fifth grade, and those who should be receiving doctorate degrees at those same ceremonies are high school sophomores today.

I mention high school sophomores for a very cogent reason. For over a decade, we have been tracking a cohort of Americans who were tenth graders--high school sophomores--in 1977, when the study began. This cohort graduated--or, more likely, did not graduate--as the college class of 1984. This study's aim was to follow changes in the cohort's science and engineering interests over a 15 year period ending in 1992.

Let me briefly review what we have learned thus far and what we can confidently predict for the remainder of the study.

There were 4 million sophomores in American secondary schools when the study began in 1977. They were initially polled about their interest in the sciences and engineering. Some three quarters of a million--about 19 per cent of the total--expressed some interest. The other side of the coin, of course, is that more than 80 per cent of the high school sophomores of 1977 were already lost to science and engineering before the study began.

The junior and senior years of high school are the period when students with some interest in science get turned on or off by what they experience in class. It is sad to note that the 750,000 interested sophomores had dwindled to 340,000 by the time that they were asked again as matriculating college freshmen what their intentions were. And it is even sadder to note that forty per cent of these science-oriented freshman either changed their major or dropped out of college by the time graduation day rolled round for the class of 1984. Of 4 million students total, three-quarters of a million of whom had some interest in science, only 204,000 students graduated with a scientific or technical degree.

I could go on and talk about further pipeline leakage through graduate school to the master's and Ph.D. levels, but I won't. I wish to concentrate on what we need to do to stanch the hemorrhagic losses in our science-education pipeline where they are greatest, namely at the pre-college and collegiate undergraduate levels.

Pre-college first. The National Science Foundation, through its directorate of Science and Engineering Education, is working closely with colleges, universities, and professional societies, as well as with state educational offices and local school districts to improve the quality of instruction in this area at the elementary, middle and secondary school levels. This is a fairly recent effort, most of it having taken place since fiscal 1983, when funding for pre-collegiate education was virtually zeroed out. Much is being done--for instance, by SEE's Division of Teacher Preparation and Enhancement--much more could be done given greater resources and support from the topmost levels of government.

Some of the most promising activities are being done in collaboration with scientific societies. Let me give you an example. The American Institute of Physics has been awarded an SEE grant for a project called "Operation Physics," which brings together middle school teachers for summer workshops at San Diego State University with the financial, administrative and programmatic support of their own schools. The objective is to improve the quality of middle-school science. Let me give you another: ChemCom, a project of the American Chemical Society, also supported by an SEE grant, aimed at developing alternatives to the traditional chemistry curricula in secondary schools.

Not to over-elaborate my message, I would just like to mention SEE's Teacher Enhancement Program, which was able to fund only about one-fourth of the 400 proposals it received each year. Not all the proposals received are worthy of support, but fully half of them are. These unfunded support-worthy proposals represent a lot of good ideas gone to waste. What does the Teacher Enhancement Program do? Well, it enables colleges and universities large and small to offer teachers additional training in scientific subjects in which they may be weak, and to give teachers who are strong in science additional training in the use of instrumentation and teaching aids that will increase their classroom effectiveness.

I could go on, but won't, turning now to the need to improve science education beyond high school. The best of our collegiate, and particularly our graduate, science education is unparalleled in the world. But not all post-secondary instruction is of the highest quality.

There is, I believe, a fundamental difference in the way NSF discharges its obligations at the pre-college and college levels, and in my view the difference is an organizational one that could easily and quickly be changed, with highly beneficial effects.

Pre-collegiate educational activities within NSF are centralized in the Directorate of Science and Engineering Education (SEE), which is entirely education-oriented, whereas much of the college level instructional support is provided by the NSF directorates, which are largely research-oriented. This is understandable, and I do not offer this observation in criticism of the other directorates, whose activities in aid of higher education have yielded rich returns for the United States. But it is certainly obvious that when research is the primary interest of an agency, non-research programs perforce will be the first to feel the pinch of shrinking budgets. I strongly urge that all science-education activities be consolidated in a single office at the National Science Foundation to enhance the teaching function which NSF is charged with fostering.

Two brief, final thoughts in a statement already overlong:

First, recall that the pipeline begins halfway through high school and ends 15 years later at the Ph.D. level. As appalling as the total picture I have drawn may be, it is worse when segments of it are examined. I refer to the losses of females and of minority students of both sexes from the pipeline. More emphasis must be placed on attracting and retaining women and minorities in the scientific enterprise, because these are the people we are going to depend on for most of our brainpower in the year 2000 and beyond. Think of this, members of the subcommittee: 85 per cent of the job vacancies that will exist at the turn of the century--only 11 years from now--must be filled by workers other than the white males who up to now have been the backbone of our labor force.

And finally, it is not enough to talk of science education just for the relative few who will become working scientists and engineers. We live in a complex scientific and technological age that can only become more complex as years go by. In order to have an effective and functional democracy, we must move forcefully to bring everyone to an appropriate level of scientific literacy--scientists and cutting-edge technologists, industrial and business managers, civilian and military public servants, the labor force; in short, everyone.

Mr. **Walgren**. Thank you, Dr. Saltman. That is strong.

Let me recognize the gentleman from California, Mr. Brown.

Mr. **Brown**. I think this panel is a good illustration of the kind of approach that we need to make to improve this teaching of science and mathematics.

My question is how can we expand on this?

I see here represented a concept of the wholeness of the educational process, the utilization of all the resources to the community, in the federal laboratory, an outstanding university. You have even brought in teacher training institutions to provide a supplement to it, and almost every community has resources of this sort. There are laboratories, there are teacher training institutions, there are research-oriented institutions of higher education. They need to work as partners, as teams, with a little inspiration.

I sense that inspiration, Dr. Saltman, in you as an excellent teacher, but you are not the only excellent teacher in the world, I hope, and we probably have some in every community.

How do we get them to working together? How do we get them to replicating this process so that it spreads throughout the society? Does it require additional funding to NSF or does it require a leadership role that isn't being played? Does it require some inspiration that we haven't figured out how to create yet?

Dr. **Saltman**. I will try to respond a little bit.

I don't think you have to reinvent the wheel every day, and what I am doing now is working with my colleagues in the Los Angeles area from USC and Cal Tech and from Stanford in the Bay Area and with Berkeley and with our friends at UC-Irvine, and what we would like to do—and again—is to make this happen everywhere.

Mr. **Brown**. Everywhere.

Dr. **Saltman**. Now, I am a realist. I can't—you know, I played basketball for Cal Tech. I know what it means to lose, so that the issue of trying to take on an opponent you cannot win, I won't play in those games anymore. I want a 50/50 chance.

I feel I can make change. I have made change happen with my colleagues' help and all of the infrastructure I talked about in San Diego. That will continue. We want to export that throughout the state.

I think that our state is particularly blessed with a concern to see that this happens and a science curriculum that it can be done. I am trying to subvert Michigan. I have secret agents at this very moment working to get Michigan to move in similar directions, but using their faculty, using their institutions, using their infrastructures coherent with the problems that they face in that state.

You talked earlier, Mr. Chairman, about a national mandate. I get very nervous. I don't want the chairman of my department to mandate my curriculum in biology when I teach it. That is my arrogance.

But on the other hand, I have to be responsible to let that curriculum show and be judged by anyone who cares to do so.

So when you say do you need money to do this, yes. These are not freebies. It costs money to do education just like it costs money to do research. If we didn't have approximately a million dollars from the NSF, our program would die a-borning. There would be no teachers.

Mr. WALGREN. If the gentleman would yield, let me just add, if I might, where that NSF money was detailed in this program. You said at one point that it was necessary for that to be there to bring the teachers in.

How was the NSF money used—bring the elementary teachers in.

Dr. SALTMAN. Yes.

Mr. WALGREN. How was the NSF money used in this program? Who got it?

Dr. SALTMAN. We subsidized every teacher $2,000 per summer to come to that institute because they need the money. They can't do this on their own

Mr. WALGREN. $2,000?

Dr. SALTMAN. Yes, and it was $2,000 a year, for which they had the commitment to come to the classes, to attend, to take the exams, to do the studying, to do the afternoon work, to do the Saturdays, to do the—what do they call it—in-service training, even learning the vocabulary.

Mr. WALGREN. And how long was the program in weeks?

Dr. SALTMAN. Pardon?

Mr. WALGREN. How long was the program in weeks?

Dr. SALTMAN. Five weeks in the summer and all year-round.

Mr. WALGREN. Okay, thank you. I appreciate the gentleman's yielding.

Dr. SALTMAN. But it does take those resources and, yes, we did give an honoraria to the people who gave lectures, but that was small. It was who were the secretaries who had to do the communication, who paid Bob and Melanie Dean to go out to the schools on a daily basis to be the expert witnesses, to be the expert coaches and teachers to keep that level of excitement up.

That doesn't come for free.

Mr. BROWN. Well, what you are causing me to do is think through what could be done in my own Congressional district, for example, where we have a number of good institutions, including a branch of the University of California, a good teacher training institution in San Bernardino State University, a lot of leadership in the local school community, but they don't get together to interact on these kinds of things, and this is the thing that I would like to see promoted.

Dr. SALTMAN. Well, Congressman Brown, I want to see it, too, and I am perfectly prepared to bring my troop of tap dancers up into your region if they will welcome us and try to, in effect, inseminate this program.

I must say one thing. The whole thing hinges on one or more small cabala almost of faculty members on those first class universities who are willing to take the leadership role. Without that it will never come about. It cannot be mandated by a chancellor. It cannot be mandated by a superintendent of schools.

Dr. BELL. May I also respond, Mr. Brown?

Mr. BROWN. Yes.

Dr. BELL. It does require that amount of funding. You heard Dr. Saltman say he wouldn't have done it without the NSF.

Those out there in the field that you would like to catalyze to do these sorts of things are many and varied across the country, and a lot of them already put together ideas, and so forth, and put them before the National Science Foundation, by my old division in NSF could only fund between 20 and 25 percent of those proposals. About 50 percent we judged as being really fundable, but we didn't have the resources to do anything about it.

I have heard this morning that the numbers are even increasing, but if the percentage return on the investment of time by people like Dr. Saltman continues to be so low, there will be no continuation of that effort.

Ms. BARDEEN. If I might add something, too.

I think we feel in a little different situation because we are not a part of the regular education community, and in our situation we have this tremendous resource, but some of us at the grass roots level feel that what we need is some leadership from Washington; for example, from the new Secretary, to say to scientists, yes, this is important and you will receive reward, not necessarily in terms of money but at least we are not going to slap your hand if we find out you spent the morning at a school.

So when we talk about collaboration and cooperation, perhaps there are ways that NSF and people here in Washington in federal agencies and representatives of universities can get together to empower their own staff to do this kind of thing and to say that the importance is such that we are all going to work together.

It will only succeed if you have people at the grass roots level to make it succeed, but they need the encouragement from above to try.

Mr. BROWN. I have no further questions.

Mr. WALGREN. The Chair recognizes the gentle lady from Maryland, and at some point here I have got to come to grips with the fact that we have six more witnesses and 45 minutes in which to dispose of them, and I apologize for saying that because I wanted to recognize you first.

Mrs. MORELLA. Thank you, Mr. Chairman. Also, I have another meeting in this very room at 1:30.

So this is the kind of thing that goes on in Congress, as you understand.

I couldn't agree more with what you have said, and indeed I have already scanned the testimony of the teachers that are going to be following you, too, as an educator myself.

I just wanted to ask Dr. Saltman, where did you get these teachers from? Are you working with the creme de la creme of teachers to begin with, or—you know, I think that is——

Dr. SALTMAN. Do you want me to be honest with you?

Mrs. MORELLA. I want you to be honest because I think it is critical to where we go.

Dr. SALTMAN. We went out on an announcement to every elementary school principal, every elementary school superintendent and district in San Diego City and County, and we said we are looking for 100 terrific teachers, and you know how many applied? 102. And we took them all.

Are we creme de la creme? We gave no competitive exam, no SAT scores, no grades, no curriculum, no essays. You want to come play, you come play.

I wish I could say that every teacher in San Diego wanted to be a part of that. They didn't at T-zero. I will tell you, we have a couple hundred more who want it now. They said, why didn't you tell me it was going to be so terrific?

Mrs. MORELLA. Well, if you can get the multiplier effect to work, that is fine.

Dr. SALTMAN. It is going to happen.

Mrs. MORELLA. But you see your difficulty is you are starting off with those people who already have the enthusiasm and understand what teaching is all about and that some of the others that are involved in the classroom that really do——

Dr. SALTMAN. I wish I could agree with you.

Mrs. MORELLA. Really?

Dr. SALTMAN. And you know what, they cared, and caring is not enough. I am an animal. You got to know and care.

Mrs. MORELLA. Right, right.

Dr. SALTMAN. So I had a lot of caring people in that room on day one, but now I have got a lot of caring and knowing people, and they are going to get more knowledgeable and more caring.

Mrs. MORELLA. Sure, but you start off with an attitude, an attitude to develop to.

Dr. SALTMAN. That is right. They were willing to come in and play.

Mrs. MORELLA. Absolutely. So you are going to have to also consider moving into getting the other teachers who have our kids in the classroom to be so injected with this kind of enthusiasm for excellence.

Dr. SALTMAN. Give me five more years. I will have 60 percent of the teachers in San Diego in hand.

Mrs. MORELLA. Thank you.

Thank you, Mr. Chairman.

Mr. WALGREN. The gentleman from Iowa, Mr. Nagle.

Mr. NAGLE. I appreciate the experience you had with the basketball team. I sit here in constant dread that the University of Iowa is going to issue a recall on my degree, and they will if I don't go to lunch with them downstairs.

But, Dr. Bell, I was curious about your testimony, you know, from a couple of aspects. On page 7, you said "Last year we looked with hope as the Division of Undergraduate Education was established within the SEE, and we were at first encouraged by the rhetoric announcing NSF's plans for undergraduate education, but a closer analysis has turned the hope to disappointment and finally to dismay."

Do you feel that there is a lack of emphasis in NSF on the types of programs that we are talking about here today?

Dr. BELL. Yes.

Mr. NAGLE. And tell me why that attitude over there. You have obviously had a very frustrating experience with them. I think I gather that from your testimony.

Dr. BELL. Well, I had a frustrating experience in some ways, and it was a very rewarding experience in others. It was rewarding because we did put together programs at the precollege level which are still intact and with the kind of focus which we have heard about here this morning.

I am frustrated because I have a vested interest in the collegiate level. I am a collegiate level professor myself, as Dr. Saltman is, and we have an interest in seeing that the problems at our level are also addressed.

The Neal report basically lays out—and this is the programmatic part—lays out a very reasoned approach with resources allocated to a whole series of programs, types of programs that will revitalize undergraduate education in science, engineering, and mathematics.

The Foundation has not put into effect most of those recommendations. There is an instrumentation program, but it is ill-funded. There is a faculty enhancement program, but it is funded at about 20 percent of what it should be actually to have any effect.

Mr. NAGLE. Now, is it a question of good programs chasing too little money, or is it a case——

Dr. BELL. In some cases the programs have simply not been allowed to develop.

Mr. NAGLE. The question I have is why?

Dr. BELL. I believe that that is a management decision by the Director, which I don't agree with, that has taken the responsibility and the authority out of the SEE directorate and distributed it among the research directorates that simply ill-equipped to handle the burden.

I think in fact it is undermining their legitimate and appropriate role, which is to fund research.

Mr. NAGLE. Let me ask you to step on the other side of the table and imagine that you were the Director. What would his rationale be for justification for those decisions, and why would his rationale be in error and lay out the arguments for me?

Dr. BELL. I am not exactly sure what his rationale is. I think the rationale is that you have an organization, the National Science Foundation, that knows something about how research is carried out and it has an expertise in that area, and that that expertise can somehow be translated into effective programs also to effect the undergraduate curriculum for the undergraduate education, and I think that that is a justifiable argument when you are talking about research, especially when you are talking about things like undergraduate research and research at undergraduate institutions, which are funded and are funded through the research directorates. I think that is an appropriate role for the research directorates.

It is when they come to thinking about curriculum and instruction that their expertise simply isn't there, and they have not put together programs in those areas.

Mr. NAGLE. I don't even know if I would agree with the undergraduate research funding. I think we saw some studies in this committee room two years ago that indicated that it was in fact one of the impediments to undergraduate progression, progressing to the BA or the MA or the PhD level, was the fact that undergraduate research had been cut rather dramatically.

Dr. BELL. Well, that is certainly true. The undergraduate research was cut of course to zero for several years. It is now back in some form. I don't agree with the form necessarily. The form tends to favor the very large research institution as a carrier of these programs rather than—and I must confess now to a prejudice—the relatively smaller undergraduate colleges like my own, where a very large amount of that research used to go on, but now we are in a very uncompetitive situation because the demands for those grants—I mean, the demands for the projects are so large that we can't carry those kinds of programs out.

Mr. NAGLE. And yet if I remember that testimony from a couple of years ago—and this is kind of as an aside—but if I remember the testimony from a couple of years ago, you have got a better chance of advancing to the PhD level if you are in a smaller school than you do if you are in the ones that are on TV on Saturday afternoon.

Dr. BELL. That is right. The statistics are all in favor of the smaller colleges; that is, the percentage of their graduates going on to getting advanced degrees is larger than at the major large institutions. That is certainly true. It has been true for decades now.

Mr. NAGLE. Let me advance, if I can, then because the Chairman's time is exceptionally limited here and he has been very kind to me, but let me advance a hypothesis if I could, using one of the few scientific terms that I know.

Dr. BELL. "Advance"?

Mr. NAGLE. "Hypothesis."

Dr. BELL. Oh, "hypothesis." [Laughter.]

Mr. NAGLE. I don't know. I will have to look up "advance," but "hypothesis" I think I remember.

But let me ask you this.

It seems to me that the direction and emphasis of the NSF in recent years has been on quick turnaround research, research that will lead directly in the applied areas as opposed to seminal, and that we are looking immediately for products as quickly as we possibly can find them that will make American industries more competitive and, going to that end of the scientific research schedule, we are neglecting a whole host of other identifiable needs.

Would you agree with that hypothesis?

Dr. BELL. Yes.

Mr. NAGLE. Okay. The second aspect of it is please explain to me if you can—and this may not be answerable—but not only have you lost the battle at NSF; you seem to have—all of you seem to have drastically lost the battle with the Administration on their budget submissions for this year.

The thing that concerns me is that I read, for example, your predecessor panel's testimony about our rank in math, science, engineering achievement of high school students, et cetera, our need for science and math teachers, the absence of the numbers coming out of the universities. Public opinion will drive Congress and will drive Administrations.

Do you have any thoughts about how we change public opinion to recognize some of the problems that you are identifying here?

This goes to a very, very essential area, the survival of our economy and our nation.

Dr. BELL. You are right, and I don't have any quick fixes. I think that is another one of those long term—I mean, it is the long-term aspect of research as well. You don't expect to get return tomorrow on your investment in fundamental research. You don't expect to get return tomorrow on your investment in science or any education. You expect that to be long term.

My liberal prejudice is that over the long term better education will in fact make a difference, but in the short term somebody has to take the leadership role and make sure that the appropriate kinds of education take place, and I think in science, mathematics, and engineering education that leadership role is the NSF's. They are the ones who have to catalyze that kind of change.

With the educational system being hundreds of billions of dollars and the NSF role in that being a couple of hundred million, it can't have an enormous effect overnight. It has got to be on a long-term basis. It has got to be sustained.

That is why I am so pleased that this committee and Appropriations have over the years made sure that that kind of sustained funding is there.

Mr. **Walgren**. Let me ask if the gentleman might pursue further in writing or something. I apologize because I am starting to not treat the other witnesses fairly that are yet to come.

I want to express my appreciation to all of you and call the next panel. Thanks for coming. We look forward to talking with you in the future.

Loring Coes, Jo Ann Mosier, and Kathryn Keranen, if you would come join us, and I want to invite you to give us some thoughts in the seven-minute range, I think. I apologize to you. You are the folks who deserve the apology because if we had saved some time earlier we would have more now.

But there is a follow-on hearing in this room that is going to create a problem for us in a little while.

So let me ask you to give us a good seven minutes, and then let's see where we are.

Let's start with Mr. Coes.

STATEMENT OF LORING COES III, MATHEMATICS CHAIRMAN, ROCKY HILL SCHOOL, GREENWICH, RI

Mr. **Coes**. Thank you very much, Mr. Chairman, for inviting me here today.

My teacherly instincts remind that we are near lunch and that in order to preserve the audience we have I am going to hit one point very, very hard and remind everybody that I have made a couple of other points in my written statement.

The issue I would like to talk about is the state of elementary mathematics and science education. This is an area of great concern to me and to many other educators. We have many elementary teachers in this country who are uncomfortable with mathematics and science, who have relatively little training in those areas and often don't like teaching those subjects.

That is a serious problem for us, and we need to address that right now and produce some reforms that help us correct the situation. We need to identify leading teachers at the elementary level and have them help others become better.

We also need to investigate the possibility of turning much of science and mathematics education at the elementary level over to experts; in other words, to get away a bit from the single teacher classroom that we have grown accustomed to and to perhaps break up the elementary day more than we have in order to get more expertise into math and science.

That is a reform that is popular among educators. It has received a good amount of attention in the literature, and it is something that we need to try. *It is something, also, that the National Science* Foundation can support, and it would be a good idea to work on this very idea.

This whole problem is compounded by the state of curricular materials at the elementary level. There was a study published in the Arithmetic Teacher in September of 1987 that showed that the four most popular textbooks used in this country are about 70 percent review at grades 4, 5, 6, and 7. In other words, kids at that level very rarely see new material, new challenging material, things that might interest them.

And this 70 percent figure is very conservative. A page was considered new in a textbook if it had any idea or any scale or any term or any picture that was new and had not been seen before. So the 70 percent figure is quite conservative.

In other words, we spend the early years of mathematics education reviewing, practicing mechanical skills over and over again, and we do not in any way promote the kind of critical thinking that we need to have students develop, and this is a critical issue. We absolutely need to change this pattern.

Now, these two problems that I have mentioned are related. In order to get teachers away from these repetitive textbooks, we need to have teachers who are comfortable teaching real mathematics and real science, of course, ant that is important. If we don't do that, if we don't win this battle, we will not win any others. If we can start to produce elementary school students who like science and like mathematics and like it with enthusiasm and want to pursue it, then we will start winning some battles at the upper levels.

Too often we have found that kids by the junior high level have already formed their negative opinions about math and science, and it is very, very difficult to change their attitudes at that point.

Let me shift a bit and talk about two programs, two NSF programs, that I have been familiar with and I think deserve continued attention.

One is the Woodrow Wilson Fellowship Foundation Program in Science and Mathematics. I was a participant at Princeton University two years ago in the institute there, and other participants and I have since then gone on to offer workshops to other teachers around the country, and it has been a very, very productive experience for me. It has allowed me to fight the staleness that can afflict teachers.

It is very, very easy for people in my profession to go stale, to get bored, burn out, and so forth, and it is important for everybody in my kind of a job to do something different once in a while to get recharged, and that is essential. We can't economize on that point.

The Woodrow Wilson Foundation has grown. It has great respect, is afforded great respect throughout the educational community. It needs to be funded by NSF and by private industry. That is essential. We must continue this.

The other NSF project that is very good is now a series of booklets that I use in my school. It is called the Quantitative Literacy Series. It is a series of booklets on probability in statistics that brings real world mathematics, real data into the classroom and allows kids to see what mathematics can really do.

Too often in our high school mathematics curriculum we are in a race to get kids to calculus as fast as possible and in pursuing this goal so quickly we often drop out much material that is of great interest to kids, and we need to stop this because we are losing many, many students along the way.

We have produced generations of people in this country who don't like mathematics, who fail to see any utility in mathematics, and the quick trip to calculus is part of the reason for that, and we need to get real data, real analysis into the everyday classroom of all of our students.

And that goes hand in hand with our need to get technology into the classrooms. Students need to be conversant with computers and calculators. They need to be able to handle these things in a businesslike fashion. We must do this.

I am confident that we have the ability to solve our problems. Our students have as much ability as anybody else in the world. We have lots and lots of teacher talent out there. We need to tap it. We need to encourage it.

We also need to be happy with the idea that education is a long-term investment. If we improve the education of our students today, it will not be measurable in the economy for years to come. We have to accept that and be happy with that. That is the way it is. But we must not ignore it. If we do ignore it, our problems as we know them so well will continue to grow, and that cannot happen. We must accept the idea that we need to invest time and effort and political power and whatever other power, whatever other zeal we can find into this deep problem.

Thank you.

[The complete prepared statement of Mr. Coes follows:]

A Report on Mathematics and Science Education to the U. S. House of Representatives Subcommittee on Science, Research, and Technology

March 9, 1989

Loring Coes III
Rocky Hill School
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Thank you for the opportunity to speak here today.

I would also like to thank my colleagues at Rocky Hill School and in the Rhode Island Mathematics Teachers Association for sharing their thoughts about what should be done to improve mathematics and science education.

The National Science Foundation has played a prominent role in the current reform of high school science and mathematics. NSF has provided some excellent teacher training and teacher enhancement programs, and has helped to develop some highly productive curricular materials.

I will not summarize the reports that prove the need for reform. The Mathematics Report Card and The Science Report Card both give ample evidence that we have failed to teach the skills of math and science very well, and that we have also failed to nurture the curiosity, the spirit of discovery, and the love of learning that are essential to the healthy growth of science. The National Research Council's recent report, Everybody Counts, also provides excellent commentary on our failures in mathematics education. The picture is bleak.

We need to change our goals and our teaching methods. The traditional high school mathematics curriculum is designed to get the brightest students to calculus as quickly as possible, because calculus is the language of science and engineering. In doing so, however, we have stripped away from early high school math a great deal of material that would capture the interest of students and that would allow mathematics to make better sense. To get to calculus by the senior year of high school, students must master a large body of abstract skills whose real value is rarely apparent. To the Algebra I student we can only say, "You'll need this skill in Algebra II," and to the Algebra II student we say, "You'll need this in pre-calculus," and in pre-calculus we say, "You'll need this next year." The bewildered student who asks, "When am I ever going to use this?" is asking a very good question. Some bright, hard-working students who like puzzles thrive in this kind of system, but there are plenty of bright people for whom this system seems a dead end. When and if a student *does* get to calculus, there are many interesting, real-world problems to solve, but we lose far too many students along the way.

For our average students across the country we have offered a slowed down and watered down version of the same program. Although they may not take calculus, we still get them ready for it. These students will also have to wait for the next course or for a career in engineering to see the value of what they study.

For the nation's non-college bound students, we offer twelve years of arithmetic. From my own observations, a shocking number of our high school seniors, if they have not dropped mathematics already, are at this very minute practicing addition, subtraction, multiplication and division of whole numbers with paper and pencil. Their experience with math is one of mind-numbing repetition. They are doing so because of their ongoing failure to get any better at these skills, and despite clear evidence that this policy is unproductive.

Rarely in these traditional courses do students see math in its real context, where is is a powerful tool to solve real problems. We teach and preach mechanical skill at the expense of critical thinking. And we teachers lose sight of the fact that, though students might master the skills for the chapter tests, there is relatively little understanding of where the skill might be used. We have trained our students to expect quick, clean answers to textbook problems, and this leaves them frustrated when forced to deal with real problems requiring clear thinking through many steps.

We need to turn our emphasis to solving real problems that have clear value and interest to students. In that real context we can motivate the skills that lead to calculus and beyond. This makes good pedagogical sense. We earn better if ideas can be made tangible, and real problems promote critical and creative thinking by doing just that.

We also need to reform our teaching methods. Traditionally the math classroom sees a teacher at the chalkboard explaining new ideas, and doing examples while students watch and hopefully remember. The teacher is the explainer; the student, the repeater. It is clear to me that this strategy, while productive in moderation, must be mixed with lessons where students are actively involved in the process of doing mathematics, looking for patterns, of experimentation, and finding profit and understanding in their errors. That is the way mathematics really operates.

I would like to tell you about two NSF projects that have helped me to mplement some of these reform measures in my own work. I attended the Woodrow Wilson Institute on High School Mathematics in the summer of 1987 at Princeton University. (While my institute was evidently funded argely by private industry, the sister institutes in chemistry and physics were funded by NSF.) It was the most stimulating professional experience I ave ever had. The institute brought bright and eager teachers together and allowed us to work with prominent mathematicians and educators. The esult was a collection of new curricular material designed to bring the freshness of the real world into our classrooms. We developed material on the mathematics of sports, of highway traffic, of selling pizza, and of many other subjects. It is important to understand that, in providing real problems like these, we are not making the mathematics *easier* or less sophisticated. The mathematics in these lessons was as complex and challenging as any in any traditional program.

Perhaps the best thing about the Woodrow Wilson Institutes is that they do not stop. Participants in the Princeton summer programs are charged and funded to go out and teach other teachers what they have learned. It is a productive way to get the message to many people. It is essential to develop a new tradition in which teachers learn new skills and renew their own commitment to teaching. Teaching is a profession where it is very easy to go stale, and the NSF institutes have played a fine role in countering this problem. They must continue, and we must try to expand these efforts to reach more people.

My school has just adopted The Quantitative Literacy Series, a set of four booklets for high school students on probability and statistics first developed through an NSF grant. We have woven this material into our average college-bound algebra program at Rocky Hill. The statistics material motivates the algebra, and the algebra supports the investigations into statistics. It has proved to be a productive and interesting experience for our students and for our teachers. We plan to continue to use this material and to experiment with the particular techniques we use to teach it.

Implementing changes like these on a broad scale is difficult. Plenty of teachers are reluctant to change and to experiment. Many teachers are discouraged from reform and experimentation by rigid curricular guidelines. It has been painfully slow, for example, for this country to get available technology into the classroom, although it is crystal clear that technology *must* be in the classroom. It is essential for school administrators to be key agents of change. And all teachers and administrators are aware of testing results and must, in some way, answer to them. And so it is clear that reform in schools will require reform in the whole process of assessment. It is vital that NSF and every one in a position of leadership actively promote the reform of testing. Our world is changing rapidly, and education, always slow to respond to *any* change, must try to do a better job in promoting what our citizens really need to know. The National Council of Teachers of Mathematics (NCTM) has for years advocated the use of calculators, and calculators are ubiquitous in business and industry, but there is not one major test I know of involving these machines. By far the best, most far-reaching set of guidelines for us to use is contained in Curriculum and

Assessment Standards for School Mathematics, an overview of which accompanies this document. The Standards, to be published in April by the National Council of Teachers of Mathematics, make up a refreshing document driven by the need to make better thinkers of our students, to show the value of mathematics, and to bring mathematics education in line with the technological nature of our modern world. The Standards already enjoy the broad support of most teachers who have seen the draft versions, a situation unlike the reception given New Math many years ago. The Standards represent a grass roots reform movement of mathematics teachers and education researchers, and they deserve the support of political and industrial leaders.

One major problem we must address is the state of elementary science and mathematics education. Many elementary school teachers have only minimal training in mathematics and science, and plenty of these people would rather not teach these subjects if given a choice. Yet our system demands that all elementary teachers cover all the subjects in addition to giving the extra personal attention that all young children need. Compounding this problem is the fact that the content of traditional elementary textbooks--and hence the *de facto* curriculum--is dull, boring, unchallenging, and only marginally aware of technology. The Arithmetic Teacher of September, 1987 reported that, in the upper elementary grades the most popular textbooks were 70% review. (In this study, a page was considered new if it contained *any* new topic, skill, or vocabulary. The 70% figure is conservative.) Only rarely do young students see new ideas, and most of their time is spent practising old mechanical skills. The first years in mathematics--the most important ones for most people--are not good ones. Negative attitudes about mathematics and science are spawned here, and these attitudes are tenacious. I want to make it clear that my criticism is of the educational *system*, not of the teachers. Elementary teachers are simply expected to master too much. Specialists in math and science, people with skill and enthusiasm for these subjects, would help the problem a great deal. We will perhaps have to sacrifice some of the emotional bonding in the single-teacher classroom, but I believe it is necessary to do so.

Teachers at that level are pulled in many different directions. Few of them belong to organizations like the National Council of Teachers of Mathematics, and hence they are hard to reach with messages of reform. NSF has funded some elementary workshops and research projects, but here is an area where I believe the effort really must be increased. If we do not win this battle, we will not win any others. At the end of my summer at Princeton, the participants were asked what topic should be treated for the next summer. Some of us suggested middle school mathematics, and we were told that it was difficult to get funding for projects dealing with young students. Evidently it is relatively easy to find funding for university projects, less so for secondary, and downright difficult for elementary projects. This must be changed. We must reach students in their formative years. We must accept and be happy with the idea that education is a long-term affair where positive results can only be obtained after many years of effort. There are no quick answers, and I think we all know that this is true.

Can we solve our problems? I am optimistic about our ability to do so. We need to show that we have the national will to do so. I know that our students have as much raw talent as any students in the world. I also know that we have enough teaching talent to make the changes we need to make. We need to have the government's help, through NSF and other agencies, in showing our teachers and schools that there can be useful reform. It is important that teachers be empowered to experiment about better ways of doing their jobs. School administrators must make this happen. This is essential to the self-esteem of any professional and to the battle against staleness that all teachers face.

It is essential for us to remember one more point. Your support of mathematics and science is vital, but we cannot neglect the English teachers, the history teachers, the language teachers, and all the other specialists in my profession. The Presidential Award which has brought resources and distinction to me also should be started for other specialties. None of us works in a vacuum. My students need to read and write well to learn in order to learn mathematics well. History students need mathematics to understand the economic forces in the world. While the most obvious solution to our technological deficit is to pump support into math and science education, the best solution, and the most lasting one, will be to support all elements of the educational community with all the resources and all the zeal we can find.

Thank you.

BIOGRAPHICAL INFORMATION: LORING COES III

Williams College, BA in English, 1971
Worcester Polytechnic Institute, Master of Mathematics, 1986

Chairman of Mathematics Department, Rocky Hill School, Ives Road, East Greenwich, Rhode Island, 1980-present

President, Rhode Island Mathematics Teachers Association, term 1988-1991

1988 Presidential Awardee in Mathematics

1987 Woodrow Wilson Fellow in Secondary Mathematics Teaching

1971-1974, Fourth Grade Teacher, Georgetown Day School, Washington, D.C.

1974-1980, Teacher of English and History, Fifth and Sixth Grades, Rocky Hill School, East Greenwich, Rhode Island

OVERVIEW OF
THE CURRICULUM AND EVALUATION STANDARDS
FOR
SCHOOL MATHEMATICS

(An Abridgement and Excerpts)

Prepared by the Working Groups

of the

COMMISSION ON STANDARDS FOR SCHOOL MATHEMATICS

of the

NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS

OCTOBER, 1988

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INTRODUCTION

Background

These standards are one facet of the mathematics education community's response to the call for reform in the teaching and learning of mathematics.[1] They reflect, and are an extension of, the community's responses to those demands for change.[2] Inherent in this document is a consensus that all students need to learn more, and often different, mathematics and that instruction in mathematics must be significantly revised.

As a function of NCTM's leadership in current efforts to reform school mathematics, the Commission on Standards for School Mathematics was established by the Board of Directors and charged with two tasks:

1. Create a coherent vision of what it means to be mathematically literate in a world that relies on calculators and computers to carry out mathematical procedures, and in a world where mathematics is rapidly growing and is extensively being applied in diverse fields.

2. Create a set of standards to guide revision of school mathematics curriculum and associated evaluation toward this vision.

The Working Groups of the Commission prepared the Standards in response to this charge.

Key terms used in the development of this document include:

Curriculum. A curriculum is an operational plan for instruction that details: what mathematics students need to know, how students are to achieve the identified curricular goals, what teachers are to do to help students develop their mathematical knowledge, and the context in which learning and teaching occurs. In this context, the term describes what many would label as the "intended curriculum," or the "plan for a curriculum."
Evaluation. Standards have been articulated for evaluating both student performance and curricular programs, with an emphasis on the role of evaluative measures in gathering information upon which teachers can base subsequent instruction. The standards also acknowledge the value of gathering information about student growth and achievement for research and administrative purposes.

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[1] See *A Nation at Risk* (National Commission on Excellence in Education, 1983), or *Educating Americans for the 21st Century* (National Science Board Commission on Precollege Education in Mathematics, Science and Technology, 1983).

[2] *What is Fundamental and What is Not* (Conference Board of the Mathematical Sciences, 1983a); *New Goals for Mathematical Sciences Education* (Conference Board of the Mathematical Sciences, 1983b); and *School Mathematics: Options for the 1990's* (Romberg, 1984).

Standard. A standard is a statement that can be used to judge the quality of a mathematics curriculum or methods of evaluation. Thus, standards are statements about what is valued.

The Need for Standards for School Mathematics

For NCTM the development of standards as statements of criteria for excellence in order to produce change was our focus. Schools, and in particular, school mathematics, must reflect the important consequences of the current reform movement if our students are to be adequately prepared to live in the 21st century. The standards should be viewed as facilitators of reform.

The Need For New Goals

Our vision of mathematical literacy is based on a reexamination of educational goals. Historically, societies have established schools to:

-- transmit aspects of the culture to the young, and

-- direct students toward and provide them with an opportunity for self-fulfillment.

Thus, the goals all schools try to achieve are both a reflection of the needs of society and the needs of students.

Calls for reform in school mathematics suggest that new goals are needed. All industrialized countries have experienced a shift from an industrial to an information society, a shift that has transformed both the aspects of mathematics that need to be transmitted to students and the concepts and procedures they must master if they are to be self-fulfilled, productive citizens in the next century.

The Information Society. This social and economic shift can be attributed, at least in part, to the availability of low-cost calculators, computers, and other technology. The use of this technology has dramatically changed the nature of the physical, life, and social sciences; business; industry; and government. Today, the pace of economic change is being accelerated by continued innovation in communications and computer technology.

New Societal Goals. The educational system of the industrial age does not meet the economic needs of today. New social goals for education include: (1) mathematically literate workers, (2) lifelong learning, (3) opportunity for all, and (4) an informed electorate. Implicit in these goals is a school system organized to serve as an important resource for all citizens throughout their lives.

Mathematically literate workers. Businesses no longer seek workers with strong backs, clever hands, and "shopkeeper" arithmetic skills. In fact, it is claimed that the "most significant growth in new jobs between now and the year 2000 will be in fields requiring the most education" (Lewis, 1988, p. 468). Henry Pollak (1987), a noted industrial mathematician, recently summarized the mathematical expectations for new employees in industry:

-- the ability to set up problems with the appropriate operations;

- knowledge of a variety of techniques to approach and work on problems;
- understanding of the underlying mathematical features of a problem;
- the ability to work with others on problems;
- the ability to see the applicability of mathematical ideas to common and complex problems;
- preparation for open problem situations, since most real problems are not well formulated; and
- belief in the utility and value of mathematics.

Notice the difference between the skills and training inherent in these expectations and those acquired by students working independently to solve explicit sets of drill and practice exercises. While mathematics is not taught in schools solely so students can get jobs, we are convinced that in-school experiences reflect to some extent those of today's workplace.

Lifelong learning. Employment counselors, cognizant of the rapid changes in technology and employment patterns, are claiming that, on average, workers will change jobs at least four to five times during the next 25 years, and that each job will require retraining in communication skills. Thus, a flexible workforce capable of lifelong learning is required; this implies that school mathematics must emphasize a dynamic form of literacy. Problem solving--which includes the ways in which problems are represented, the meanings of the language of mathematics, and the ways in which one conjectures and reasons--must be central to schooling so that students can explore, create, accommodate to changed conditions, and actively create new knowledge over the course of their lives.

Opportunity for all. The social injustices of past schooling practices can no longer be tolerated. Current statistics indicate that those who study advanced mathematics are most often white males. Women and most minorities study less mathematics and are seriously underrepresented in careers utilizing science and technology. Creating a just society in which women and various ethnic groups enjoy equal opportunities and equitable treatment is no longer an issue. Mathematics has become a critical filter for employment and full participation in our society. We cannot afford to have the majority of our population mathematically illiterate: Equity has become an economic necessity.

Informed electorate. In a democratic country in which political and social decisions involve increasingly complex technical issues, an educated, informed electorate is critical. Current issues--such as environmental protection, nuclear energy, defense spending, space exploration, and taxation--involve many interrelated questions. Their thoughtful resolution requires technological knowledge and understanding. In particular, citizens must be able to read and interpret complex, and sometimes conflicting, information.

In summary, today's society expects schools to insure that all students have an opportunity to become mathematically literate, are capable of extending their learning, have an equal opportunity to learn, and become informed citizens capable of understanding issues in a technological society. As society changes, so must its schools.

New Goals for Students. Educational goals for students must reflect the importance of mathematical literacy. Toward this end, the *Standards*, K-12, articulate five general goals for all students: (1) that they learn to value mathematics, (2) that they become confident in their ability to do mathematics, (3) that they become mathematical problem solvers, (4) that they learn to communicate mathematically, and (5) that they learn to reason mathematically. The curriculum should be permeated with these goals and experiences such that they become commonplace in the lives of students. We are convinced that if students are exposed to the kinds of experiences outlined in the *Standards*, they will gain *mathematical power*. This term denotes an individual's abilities to explore, conjecture, and reason logically, as well as the ability to use a variety of mathematical methods effectively to solve nonroutine problems. This notion is based on recognition of mathematics as more than a collection of concepts and skills to be mastered; it includes methods of investivating and reasoning, means of communication, and notions of context. In addition, for each individual, mathematical power involves the development of personal self-confidence.

Learning to value mathematics. Students should have numerous and varied experiences related to the cultural, historical, and scientific evolution of mathematics so that they can appreciate the role of mathematics in the development of our contemporary society, and explore relationships among mathematics and the disciplines it serves: the physical and life sciences, the social sciences, and the humanities.

Becoming confident in one's own ability. As a result of studying mathematics, students need to view themselves as capable of using their growing mathematical power to make sense of new problem situations in the world around them. To some extent, everybody is a mathematician and does mathematics consciously. To buy at the market, to measure a strip of wallpaper or to decorate a ceramic pot with a regular pattern is doing mathematics. School mathematics must endow all students with a realization that doing mathematics is a common human activity. Having numerous and varied experiences allows students to trust their own mathematical thinking.

Becoming a mathematical problem solver. Development of each student's ability to solve problems is essential if he or she is to be a productive citizen. We strongly endorse the first recommendation of *An Agenda for Action* (National Council of Teachers of Mathematics, 1980): "Problem solving must be the focus of school mathematics" (p. 2). To develop such abilities, students need to work on problems that may take hours, days and even weeks to solve. Although some may be relatively simple exercises to be accomplished independently, others should involve small groups or an entire class working cooperatively. Some problems also should be open-ended with no right answer, or need to be formulated.

Learning to communicate mathematically. Development of a student's power to use mathematics involves learning the signs, symbols, and terms of mathematics. This is best accomplished in problem situations in which students have an opportunity to read, write, and discuss ideas in which the use of the language of mathematics becomes natural As students communicate their ideas, they learn to clarify, refine, and consolidate their thinking.

Learning to reason mathematically. Making conjectures, gathering evidence, and building an argument to support such notions are fundamental to doing mathematics. In fact, demonstration of good reasoning should be rewarded even more than students' ability to find correct answers.

In summary, the intent of these goals is that students will *become mathematically literate*. This term denotes an individual's ability to explore, to conjecture, and to reason logically, as well as to use a variety of mathematical methods effectively to solve problems. By becoming literate, their mathematical power should develop.

An Overview of the Curriculum and Evaluation Standards

There are 54 standards divided among four categories: grades K-4, 5-8, 9-12, and evaluation. The four categories are arbitrary in that they are not intended to reflect school structure; in fact, we encourage readers to consider these as K-12 standards. In addition, we believe that similar standards need to be developed for both pre-school programs and those beyond high school.

It was our task to prepare the curriculum and evaluation standards that reflect our vision of how the societal and student goals already articulated here could be met. These standards should be seen as an initial step in the lengthy process of bringing about reform in school mathematics.

The Evaluation Standards. The evaluation standards are presented separately not because evaluation should be separated from the curriculum, but because planning for the gathering of evidence about student and program outcomes is different.

Challenge

Such are the background, the general focus, and the intent of our efforts. It is now left to each of you is concerned with the teaching and learning of mathematics to read the *Standards*, to share them with colleagues, and to reflect on their vision. Consider what needs to be done and what you can do, and collaborate with others to plan and implement the *Standards* for the benefit of students, as well as for our social and economic future.

K-4 STANDARDS

STANDARD 1: MATHEMATICS AS PROBLEM SOLVING

In grades K-4, the study of mathematics should emphasize problem solving so that students can:

- use problem-solving approaches to investigate and understand mathematical content;
- formulate problems from everyday and mathematical situations;
- develop and apply strategies to solve a wide variety of problems;
- verify and interpret results with respect to the original problem;
- acquire confidence in using mathematics meaningfully.

STANDARD 2: MATHEMATICS AS COMMUNICATION

In grades K-4, the study of mathematics should include numerous opportunities for communication so that students can:

- relate physical materials, pictures and diagrams to mathematical ideas;
- reflect upon and clarify their thinking about mathematical ideas and situations;
- relate their everyday language to mathematical language and symbols;
- realize that representing, discussing, listening, writing, and reading mathematics are a vital part of learning and using mathematics.

STANDARD 3: MATHEMATICS AS REASONING

In grades K-4, the study of mathematics should emphasize reasoning so that students can:

- draw logical conclusions about mathematics;
- use models, known facts, properties, and relationships to explain their thinking;
- justify their answers and solution processes;
- use patterns and relationships to analyze mathematical situations;
- believe that mathematics makes sense.

STANDARD 4: MATHEMATICAL CONNECTIONS

In grades K-4, the study of mathematics should include opportunities to make connections so that students can:

- link conceptual and procedural knowledge;
- relate various representations of concepts or procedures to one another;
- recognize relationships among different topics in mathematics;
- use mathematics in other curriculum areas;
- use mathematics in their daily lives.

STANDARD 5: ESTIMATION

In grades K-4, the curriculum should include estimation so students can:

- explore estimation strategies;
- recognize when an estimate is appropriate;
- use estimation to determine reasonableness of results;
- apply estimation in working with quantities, measurement, computation, and problem solving.

STANDARD 6: NUMBER SENSE AND NUMERATION

In grades K-4, the mathematics curriculum should include whole number concepts and skills so that students can:

- construct number meanings through real-world experiences and the use of physical materials;

- understand our numeration system by relating counting, grouping, and place-value concepts;
- develop number sense;
- interpret the multiple uses of numbers encountered in the real world.

STANDARD 7: CONCEPTS OF WHOLE NUMBER OPERATIONS

In grades K-4, the mathematics curriculum should include concepts of addition, subtraction, multiplication, and division of whole numbers so that students can:
- develop meaning for the operations by modeling and discussing a rich variety of problem situations;
- relate the mathematical language and symbolism of operations to problem situations and informal language;
- recognize that a wide variety of problem structures can be represented by a single operation;
- develop operation sense.

STANDARD 8: WHOLE NUMBER COMPUTATION

In grades K-4, the mathematics curriculum should develop whole number computation so that students can:
- model, explain, and develop reasonable proficiency with basic facts and algorithms;
- use a variety of mental computation and estimation techniques;
- use calculators in appropriate computational situations;
- select and use computation techniques appropriate to specific problem situations and determine whether the result is reasonable.

STANDARD 9: GEOMETRY AND SPATIAL SENSE

In grades K-4, the mathematics curriculum should include two- and three-dimensional geometry so that students can:
- describe, model, draw, and classify shapes;
- investigate and predict results of combining, subdividing, and changing shapes;
- develop spatial sense;
- relate geometric ideas to number and measurement ideas;
- recognize and appreciate geometry in their world.

STANDARD 10: MEASUREMENT

In grades K-4, the mathematics curriculum should include measurement so that students can:
- understand the attributes of length, capacity, weight, area, volume, time, temperature, and angle;
- develop the process of measuring and concepts related to units of measurement;
- make and use estimates of measurement;
- make and use measurements in problem and everyday situations.

STANDARD 11: STATISTICS AND PROBABILITY

In grades K-4, the mathematics curriculum should include experiences with data analysis and probability so that students can:
- collect, organize, and describe data;
- construct, read, and interpret displays of data;
- formulate and solve problems that involve collecting and analyzing data;
- explore concepts of chance.

STANDARD 12: FRACTIONS AND DECIMALS

In grades K-4, the mathematics curriculum should include fractions and decimals so that students can:

- develop concepts of fractions, mixed numbers and decimals;
- develop number sense for fractions and decimals;
- use models to relate fractions to decimals and to find equivalent fractions;
- use models to explore operations on fractions and decimals;
- apply fractions and decimals in problem situations.

STANDARD 13: PATTERNS AND RELATIONSHIPS

In grades K-4, the mathematics curriculum should include patterns and relationships so that students can:

- recognize, extend, describe, and create a wide variety of patterns;
- represent and describe mathematical relationships;
- explore the use of variables and open sentences to express relationships.

5-8 STANDARDS

STANDARD 1: MATHEMATICS AS PROBLEM SOLVING

In grades 5-8, the mathematics curriculum should include numerous and varied experiences with problem solving as a method of inquiry and application so that students can:

- use problem-solving approaches to investigate and understand mathematical content;
- formulate problems from situations within and outside mathematics;
- develop and apply a variety of strategies to solve problems, with emphasis on multi-step and nonroutine problems;
- verify and interpret results with respect to the original problem situation;
- generalize solutions and strategies to new problem situations;
- acquire confidence in using mathematics meaningfully.

STANDARD 2: MATHEMATICS AS COMMUNICATION

In grades 5-8, the study of mathematics should include opportunities to communicate so that students can:

- model situations using oral, written, concrete, pictorial, graphical, and algebraic methods;
- reflect upon and clarify their own thinking about mathematical ideas and situations;
- develop common understandings of mathematical ideas, including the role of definitions;
- use the skills of reading, listening, and viewing to interpret and evaluate mathematical ideas;
- discuss mathematical ideas and make conjectures and convincing arguments;
- appreciate the value of mathematical notation and its role in the development of mathematical ideas.

STANDARD 3: MATHEMATICS AS REASONING

In grades 5-8, reasoning shall permeate the mathematics curriculum so that students can:

- recognize and apply deductive and inductive reasoning;
- understand and apply reasoning processes, with special attention to spatial reasoning and reasoning with proportions and graphs;
- make and evaluate mathematical conjectures and arguments;
- validate their own thinking;
- appreciate the pervasive use and power of reasoning as a part of mathematics.

STANDARD 4: MATHEMATICAL CONNECTIONS

In grades 5-8, the mathematics curriculum should include investigation of mathematical connections so that students can:

- see mathematics as an integrated whole;
- explore problems and describe results using graphical, numerical, physical, algebraic, and verbal mathematical models or representations;
- use a mathematical idea to further their understanding of other mathematical ideas;
- apply mathematical thinking and modeling to solve problems that arise in other disciplines, such as art, music, psychology, science, and business;
- value the role of mathematics in our culture and society.

STANDARD 5: NUMBER AND NUMBER RELATIONSHIPS

In grades 5-8, the mathematics curriculum should include the continued development of number and number relationships so that students can:
- **understand, represent, and use numbers in a variety of equivalent forms (integer, fraction, decimal, percent, exponential, and scientific notation) in real-world and mathematical problem situations;**
- **develop number sense for whole numbers, fractions, decimals, integers, and rational numbers;**
- **understand and apply ratios, proportions, and percents in a wide variety of situations;**
- **investigate relationships among fractions, decimals, and percents;**
- **represent numerical relationships in one- and two-dimensional graphs.**

STANDARD 6: NUMBER SYSTEMS AND NUMBER THEORY

In grades 5-8, the mathematics curriculum should include the study of number systems and number theory so that students can:
- understand and appreciate the need for numbers beyond the whole numbers;
- develop and use order relations for whole numbers, fractions, decimals, integers, and rational numbers;
- extend their understanding of whole number operations to fractions, decimals, integers, and rational numbers;
- understand how the basic arithmetic operations are related to one another;
- develop and apply number theory concepts (such as primes, factors, and multiples) in real-world and mathematical problem situations.

STANDARD 7: COMPUTATION AND ESTIMATION

In grades 5-8, the mathematics curriculum should include development of the concepts underlying computation and estimation in various contexts so that students can:
- compute with whole numbers, fractions, decimals, integers, and rational numbers;
- develop, analyze, and explain procedures for computation and techniques for estimation;
- develop, analyze, and explain methods for solving proportions;
- select and use an appropriate method for computing from among mental arithmetic, paper-and-pencil, calculator, and computer methods;
- use computation, estimation, and proportions to solve problems;
- use estimation to check the reasonableness of results.

STANDARD 8: PATTERNS AND FUNCTIONS

In grades 5-8, the mathematics curriculum should include explorations of patterns and functions so that students can:
- describe, extend, analyze, and create a wide variety of patterns;
- describe and represent relationships using tables, graphs, and rules;
- analyze functional relationships to explain how change in one quantity affects change in another;
- use patterns and functions to represent and solve problems.

STANDARD 9: ALGEBRA

In grades 5-8, the mathematics curriculum should include explorations of algebraic concepts and processes so that students can:
- understand the concepts of variable, expression, and equation;
- represent situations and number patterns with tables, graphs, verbal rules, and equations, and explore the interrelationships of these representations;

- analyze tables and graphs to identify properties and relationships;
- develop confidence in solving linear equations using concrete, informal, and formal methods;
- investigate inequalities and nonlinear equations informally;
- apply algebraic methods to solve a variety of real-world and mathematical problems.

STANDARD 10: STATISTICS

In grades 5-8, the mathematics curriculum should include explorations of statistics in real-world situations so that students can:

- systematically collect, organize, and describe data;
- construct, read, and interpret tables, charts, and graphs;
- make inferences and convincing arguments based on data analysis;
- evaluate arguments based on data analysis;
- develop an appreciation for statistical methods as powerful means for decision making.

STANDARD 11: PROBABILITY

In grades 5-8, the mathematics curriculum should include explorations of probability in real world situations so that students can:

- model situations by devising and carrying out experiments or simulations to determine probabilities;
- model situations by constructing a sample space to determine probabilities;
- appreciate the power of using a probability model through comparison of experimental results with mathematical expectations;
- make predictions based on experimental or mathematical probabilities;
- develop an appreciation for the pervasive use of probability in the real world.

STANDARD 12: GEOMETRY

In grades 5-8, the mathematics curriculum should include the study of the geometry of one, two, and three dimensions in a variety of situations so that students can:

- identify, describe, compare, and classify geometric figures;
- visualize and represent geometric figures with special attention to developing spatial sense;
- explore transformations of geometric figures;
- represent and solve problems using geometric models;
- understand and apply geometric properties and relationships;
- develop an appreciation of geometry as a means of describing the physical world.

STANDARD 13: MEASUREMENT

In grades 5-8, the mathematics curriculum should include extensive concrete experiences using measurement so that students can:

- extend their understanding of the process of measurement;
- estimate, make, and use measurements to describe and compare phenomena;
- select appropriate units and tools to measure to the level of accuracy required in a particular situation;
- understand the structure and use of systems of measurement;
- extend their understanding of the concepts of perimeter, area, volume, angle measure, capacity, and weight/mass;
- develop the concepts of rates and other derived and indirect measurements;
- develop formulas and procedures for determining measures to solve problems.

9-12 STANDARDS

STANDARD 1: MATHEMATICS AS PROBLEM SOLVING

In grades 9-12, the mathematics curriculum should include the refinement and extension of methods of mathematical problem solving so that all students can:

- use, with increasing confidence, problem-solving approaches to investigate and understand mathematical content;
- apply integrated mathematical problem-solving strategies to solve problems from within and outside of mathematics;
- recognize and formulate problems from situations within and outside of mathematics;
- apply the process of mathematical modeling to real-world problem situations.

STANDARD 2: MATHEMATICS AS COMMUNICATION

In grades 9-12, the mathematics curriculum should include the continued development of language and symbolism to communicate mathematical ideas so that all students can:

- reflect upon and clarify their thinking about mathematical ideas and relationships;
- formulate mathematical definitions and express generalizations (potential theorems) discovered through investigations;
- express mathematical ideas orally and in writing;
- read written presentations of mathematics with understanding;
- ask clarifying and extending questions related to mathematics they have read or heard about;
- appreciate the power, elegance, and economy of mathematical notation and its role in the development of mathematical ideas.

STANDARD 3: MATHEMATICS AS REASONING

In grades 9-12, the mathematics curriculum should include numerous and varied experiences that reinforce and extend logical reasoning skills so that all students can:

- make and test conjectures;
- formulate counterexamples;
- follow logical arguments;
- judge the validity of arguments;
- construct simple valid arguments;

and so that, in addition, college-intending students can:

- construct proofs for mathematical assertions, including indirect proofs and proofs by mathematical induction.

STANDARD 4: MATHEMATICAL CONNECTIONS

In grades 9-12, the mathematics curriculum should include investigation of the connections and interplay among various mathematical topics and their application so that all students can:

- recognize equivalent representations of the same concept;
- relate procedures in one representation to procedures in an equivalent representation;
- utilize and value the connections among mathematical topics;
- utilize and value the connections between mathematics and other disciplines.

STANDARD 5: ALGEBRA

In grades 9-12, the mathematics curriculum should include the continued study of algebraic concepts and methods so that all students can:

- represent situations that involve variable quantities with expressions, equations, inequalities, and matrices;
- use tables and graphs as tools to interpret expressions, equations, and inequalities;
- operate on expressions and matrices, and solve equations and inequalities;
- appreciate the power of mathematical abstraction and symbolism;

and so that, in addition, college-intending students can:

- use matrices to solve linear systems;
- demonstrate technical facility with algebraic transformations, including techniques based on the theory of equations.

STANDARD 6: FUNCTIONS

In grades 9-12, the mathematics curriculum should include the continued study of functions so that all students can:

- model real-world phenomena with a variety of functions;
- represent and analyze relationships using tables, rules, and graphs;
- translate among tabular, symbolic, and graphical representations of functions;
- recognize that a variety of problem situations can be modeled by the same type of function;
- analyze the effects of parameter changes on the graphs of functions;

and so that, in addition, college-intending students can:

- understand operations on, and the general properties and behavior of, classes of functions.

STANDARD 7: GEOMETRY FROM A SYNTHETIC PERSPECTIVE

In grades 9-12, the mathematics curriculum should include the continued study of the geometry of two and three dimensions so that all students can:

- interpret and draw three-dimensional objects;
- represent problem situations with geometric models and apply properties of figures;
- classify figures in terms of congruence and similarity and apply these relationships;
- deduce properties of, and relationships between, figures from given assumptions;

and so that, in addition, college-intending students can:

- develop an understanding of an axiomatic system through investigating and comparing various geometries.

STANDARD 8: GEOMETRY FROM AN ALGEBRAIC PERSPECTIVE

In grades 9-12, the mathematics curriculum should include the study of the geometry of two and three dimensions from an algebraic point of view so that all students can:

- translate between synthetic and coordinate representations;
- deduce properties of figures using transformations and rising coordinates;
- identify congruent and similar figures using transformations;
- analyze properties of Euclidean transformations and relate translations to vectors;

and so that, in addition, college-intending students can:

- deduce properties of figures using vectors;
- apply transformations, coordinates, and vectors in problem solving.

STANDARD 9: TRIGONOMETRY

In grades 9-12, the mathematics curriculum should include the study of trigonometry so that all students can:
- apply trigonometry to problem situations involving triangles;
- explore periodic real-world phenomena using the sine and cosine functions;

and so that, in addition, college-intending students can:
- understand the connection between trigonometric and circular functions;
- use circular functions to model periodic real-world phenomena;
- apply general graphing techniques to trigonometric functions;
- solve trigonometric equations and verify trigonometric identities;
- understand the connections between trigonometric functions and polar coordinates, complex numbers, and series.

STANDARD 10. STATISTICS

In grades 9-12, the mathematics curriculum should include the continued study of data analysis and statistics so that all students can:
- construct and draw inferences from charts, tables, and graphs that summarize data from real-world situations;
- use curve-fitting to predict from data;
- understand and apply measures of central tendency, variability, and correlation;
- understand sampling and recognize its role in statistical claims;
- design a statistical experiment to study a problem, conduct the experiment, and interpret and communicate the outcomes;
- analyze the effects of data transformations on measures of central tendency and variability;

and so that, in addition, college-intending students can:
- transform data to aid in data interpretation and prediction;
- test hypotheses using appropriate statistics.

STANDARD 11: PROBABILITY

In grades 9-12, the mathematics curriculum should include the continued study of probability so that all students can:
- use experimental or theoretical probability, as appropriate, to represent and solve problems involving uncertainty;
- use simulations to estimate probabilities;
- understand the concept of random variable;
- create and interpret discrete probability distributions;
- describe, in general terms, the normal curve and use its properties to answer questions about sets of data that are assumed to be normally distributed;

and so that, in addition, college-intending students can:
- apply the concept of random variable to generate and interpret probability distributions including binomial, uniform, normal, and chi-square.

STANDARD 12: DISCRETE MATHEMATICS

In grades 9-12, the mathematics curriculum should include topics from discrete mathematics so that all students can:
- represent problem situations using discrete structures such as finite graphs, matrices, sequences, and recurrence relations;
- represent and analyze finite graphs using matrices;
- develop and analyze algorithms;
- solve enumeration and finite probability problems;

and so that, in addition, college-intending students can:

- represent and solve problems using linear programming and difference equations;
- investigate problem situations that arise in connection with computer validation and application of algorithms.

STANDARD 13: CONCEPTUAL UNDERPINNINGS OF CALCULUS

In grades 9-12, the mathematics curriculum should include the informal exploration of calculus concepts from both a graphical and numerical perspective so that all students can:

- determine maximum and minimum points of a graph and interpret the results in problem situations;
- investigate limiting processes by examining infinite sequences and series and areas under curves;

and so that, in addition, college-intending students can:

- understand the conceptual foundations of limit, area under a curve, rate of change, and slope of a tangent line, and their applications in other disciplines;
- analyze the graphs of polynomial, rational, radical, and transcendental functions.

STANDARD 14: MATHEMATICAL STRUCTURE

In grades 9-12, the mathematics curriculum should include the study of mathematical structure so that all students can:

- compare and contrast the real number system and its various subsystems in terms of structural characteristics;
- understand the logic of algebraic procedures;
- appreciate that seemingly different mathematical systems may be essentially the same;

and so that, in addition, college-intending students can:

- develop the complex number system and demonstrate facility with its operations;
- prove elementary theorems within various mathematical structures, such as groups and fields;
- develop an understanding of the nature and purpose of axiomatic systems.

EVALUATION STANDARDS

STANDARD 1: ALIGNMENT

In assessing students' learning, assessment methods and tasks should be aligned with the curriculum in terms of:
- its goals, objectives, and mathematical content;
- the relative emphases it gives to various topics and processes and their relationships;
- its instructional approaches and activities, including the use of calculators, computers, and manipulatives.

STANDARD 2: MULTIPLE SOURCES OF INFORMATION

Decisions concerning students' learning should be based on the convergence of information obtained from a variety of sources. These sources should embody tasks that:
- demand different kinds of mathematical thinking;
- present the same mathematical concept or procedure in different contexts, formats, and problem situations.

STANDARD 3: APPROPRIATE ASSESSMENT METHODS AND USES

Assessment methods and instruments should be selected on the basis of:
- the type of information sought;
- the use to which the information will be put;
- the developmental level and maturity of the student.

Use of assessment data for purposes other than those intended is inappropriate.

STANDARD 4: MATHEMATICAL POWER

The assessment of students' mathematical knowledge should seek information about their:
- ability to apply their knowledge to solve problems within mathematics and in other disciplines;
- ability to use mathematical language to communicate ideas;
- ability to reason and analyze;
- knowledge and understanding of concepts and procedures;
- disposition towards mathematics;
- understanding of the nature of mathematics;

and the extent to which these aspects of students' mathematical knowledge are integrated.

STANDARD 5: PROBLEM SOLVING

The assessment of students' ability to solve problems should provide evidence that they can:
- formulate problems;
- apply a variety of strategies to solve problems;
- solve problems;
- verify and interpret results;
- generalize solutions.

STANDARD 6: COMMUNICATION

Assessment of students' ability to communicate mathematics should provide evidence that they can:
- express mathematical ideas by speaking, writing, demonstrating, and depicting them visually;

- understand, interpret, and evaluate mathematical ideas that are presented in written, oral or visual form;
- use mathematical vocabulary, notation, and structure to represent ideas, describe relationships, and model situations.

STANDARD 7: REASONING

The assessment of students' ability to reason mathematically should provide evidence that they can:

- use inductive reasoning to recognize patterns and form conjectures;
- use to develop plausible arguments for mathematical statements;
- use proportional and spatial reasoning to solve problems;
- use deductive reasoning to verify conclusions, judge the validity of arguments, and construct valid arguments;
- analyze situations to determine common properties and structures;
- appreciate the axiomatic nature of mathematics.

STANDARD 8: MATHEMATICAL CONCEPTS

Assessment of students' knowledge and understanding of mathematical concepts should provide evidence that they can:

- label, verbalize, and define concepts;
- identify and generate examples and nonexamples;
- use models, diagrams, and symbols to represent concepts;
- translate from one mode of representation to another;
- recognize the various meanings and interpretations of concepts;
- identify properties of a given concept and recognize conditions that determine a particular concept;
- compare and contrast concepts with other related concepts.

In addition, assessment should provide evidence of the extent to which students have integrated their knowledge of various concepts.

STANDARD 9: MATHEMATICAL PROCEDURES

The assessment of students' knowledge of procedures should provide evidence that they can:

- recognize when it is appropriate to use a procedure;
- give reasons for the steps in a procedure;
- reliably and efficiently execute procedures;
- verify results of procedures empirically (e.g., using models) or analytically;
- recognize correct and incorrect procedures;
- generate new procedures and extend or modify familiar ones;
- appreciate the nature and role of procedures in mathematics.

STANDARD 10: MATHEMATICAL DISPOSITION

The assessment of students' mathematical disposition should seek information about their:

- confidence in using mathematics to solve problems, to communicate ideas, and to reason;
- flexibility in exploring mathematical ideas and trying alternative methods in solving problems;
- willingness to persevere at mathematical tasks;
- interest, curiosity and inventiveness in doing mathematics;
- inclination to monitor and reflect upon their own thinking and performance;
- appreciation of the role of mathematics in our culture and its value as a tool and as a language.

STANDARD 11: INDICATORS FOR PROGRAM EVALUATION

When evaluating a mathematics program is consistency with the NCTM Standards, indicators of the program's match to the Standards should be collected on:
- **student outcomes;**
- **program expectations and support;**
- **equity for all students;**
- **curriculum review and change.**

In addition, indicators of the program's match to the *Standards* should be collected on curriculum and instructional resources and instruction. These are discussed explicitly in Evaluation Standards 12 and 13.

STANDARD 12: CURRICULAR AND INSTRUCTIONAL RESOURCES

When evaluating a mathematics program's consistency with the NCTM Curriculum Standards, examination of curricular and instructional resources should focus on:
- **goals, objectives, and mathematical content;**
- **relative emphases of various topics and processes and their relationships;**
- **instructional approaches and activities;**
- **articulation across grades;**
- **assessment methods and instruments;**
- **availability of technological tools and support materials.**

STANDARD 13: INSTRUCTION

When evaluating a mathematics program's consistency with the NCTM Curriculum Standards, instruction and the environment in which it takes place should be examined, with special attention to:
- **mathematical content and its treatment;**
- **relative emphases assigned to various topics and processes and the relationships among them;**
- **opportunity to learn;**
- **instructional resources and classroom climate;**
- **assessment methods and instruments used;**
- **articulation of instruction across grades.**

STANDARD 14: EVALUATION TEAM

Program evaluation should be planned and conducted with the involvement of:
- **individuals with expertise and training in mathematics education;**
- **individuals with expertise and training in program evaluation;**
- **decision makers for the mathematics program;**
- **users of the information from the evaluation.**

AN EXAMPLE OF A CURRICULUM STANDARD

STANDARD 10: STATISTICS

In grades 5-8, the mathematics curriculum should include the exploration of statistics in real-world situations so that students can:

- **systematically collect, organize, and describe data;**
- **construct, read, and interpret tables, charts, and graphs;**
- **make inferences and convincing arguments based on data analysis;**
- **evaluate arguments based on data analysis;**
- **develop an appreciation for statistical methods as powerful means for decision making.**

Focus

In this age of information and technology, there is an ever-increasing need to understand how information is processed and translated into usable knowledge. Because of society's expanding use of data in prediction and decision making, it is important that students develop an understanding of the concepts and processes used in analyzing data. Knowledge of statistics is necessary for students to become intelligent consumers who can make informed and critical decisions.

In grades K-4, students begin to explore elementary ideas of statistics by gathering data appropriate to their grade level, organizing it in charts or graphs, and reading information from their displays. These concepts should be continued and expanded in the middle grades. Students in grades 5-8 have a keen interest in trends in music, movies, fashion, and sports. Investigation of how such trends are developed and communicated is an excellent motivator for the study of statistics. Students need to be actively involved in each of the steps that comprise statistics, from the process of gathering information to the communication of findings and statistical results.

Identifying the range or average of a data set, constructing simple graphs, and reading data points as answers to specific questions are important activities, but they reflect only a very narrow aspect of statistics. Instead, instruction in statistics should focus on the active involvement of students in the entire process: formulating key questions; collecting and organizing data; representing the data using graphs, tables, frequency distributions, and summary statistics; analyzing the data; making conjectures; and communicating information in a convincing way. Students' understanding of statistics also is enhanced by opportunities to evaluate others' arguments. This exercise is of particular importance to all students, as so much advertising, forecasting, and public policy development is based on data analysis.

Discussion

Middle-school students' curiosity about themselves, their peers, and their surroundings can motivate the study of statistics. The data to be gathered, organized, and studied should be interesting and relevant; their interest in self and peers, for example, can motivate students to investigate the "average student" in the class or school. First, students must formulate questions as to what determines their concept of an "average student"--age, height, eye color, favorite music or TV show, number of people in family, pets at home, etc. While numerous categories are possible, some discussion will help students to develop a survey instrument that will provide appropriate data. Sampling procedures are a critical issue in data collection. Which students should be surveyed to determine Mr. or Ms. Average? Must every student be questioned? If not, how can randomness in the sampling be assured and how many samples are needed to provide enough data to describe the average student?

Random samples, bias in sampling procedures, and limited samples all are important considerations. For instance, would collecting data from the men's and women's basketball teams provide good information to determine the average height of a college student? Will a larger sample reveal a more accurate picture of the percentage of students with brown hair? The following graph illustrates the results of increasing the sample size.

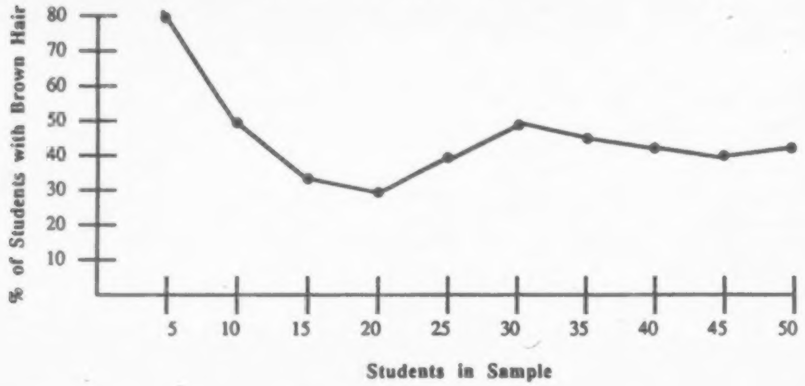

Figure 10.1: Graph of brown-haired students

number with brown hair	4	5	5	6	10	15	16	17	18	21
students sampled	5	10	15	20	25	30	35	40	45	50

Figure 10.2: Data table

Data presentation can take various forms: charts, tables, plots (including stem and leaf, box and whiskers, and scatter), and graphs (such as bar, circle, or line). Each offers its own unique visual presentation of the data. Each form wields a different impact on the picture of the information being presented, and each conveys a different perspective. The choice of form depends on the questions that are to be answered. Using the same data, graphs can be developed using several different scales to show how the change of scale can dramatically alter the visual message that is communicated.

Computer software can greatly enhance the organization and representation of data. Data-base programs can provide information for students' investigation and can record data, sort it quickly by various categories, and organize it in a variety of ways. Other programs can be used to construct plots and graphs for data display. Scale changes can be made to compare different pictures of the same information. This technological tool frees students to spend more time exploring the essence of statistics: analyzing data from many viewpoints, drawing inferences, and constructing and evaluating arguments.

A particular point to be raised with students concerns "average" as it relates to numerical and nonnumerical data. While there are several measures of central tendency, students are generally exposed only to the mean or median, yet the mode may be the best "average" for a set of non-numerical data.

Students also should explore the concepts of *center* and *dispersion of data*. The following activity includes all of the important elements presented in this standard and illustrates the use of box-and-whisker plots as an effective means of describing data and showing variation.

> **A class is divided into two large groups, and then subdivided into pairs. One student in each pair estimates when one minute has passed while the other watches the clock and records the actual time. All of the students in one group concentrate on the timing task, while half of the students in the second exert constant efforts to distract their partners. The box plots show that the median times for the two groups were about the same, but the times for the distracted group have greater variation. Note that in the distracted group, one data point is far enough removed from the others to be an outlier.**

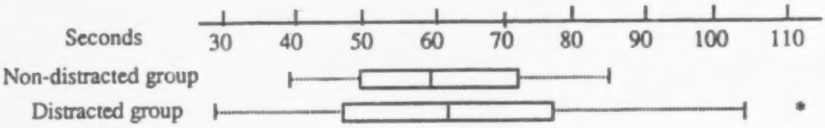

Figure 10.3: Time estimates

Sports statistics and other real data provide students with settings in which they can generate new data and investigate a variety of conjectures. The table below contains information from a NBA championship series game between Los Angeles and Boston.

Player	Min	FG-A	Reb	Asst.	Pts.
Worthy	37	8-19	8	5	20
Johnson	34	8-14	1	12	19
Bird	31	8-14	6	9	19
McHale	32	10-16	9	0	26

Figure 10.4: NBA championship series

From this table, students can be asked to generate such new information as: points/minute, rebounds/minute, points/field goals attempted. Who is the best percentage shooter? What is the height of each player? Determine rebounds/inch of height; points/inch of height.

A problem such as this is ideally suited to the curious nature of middle-school students and opens up a world of questions and investigations to them.

Formulating key questions, interpreting graphs and charts, and solving problems are important goals in the study of statistics. Statistics can help answer questions that do not lend themselves to direct measurement. Once data is collected and organized, questions such as the following can guide students in interpreting the data:

What appears most often?
What trends appear in the data?
What is the significance of outliers?
What interpretations can we draw from these data, and can we use the interpretations to make predictions?
What difficulties might be encountered when extending the interpretations or predictions to other, related problems?
What additional data could we collect in order to verify or disprove the ideas developed from these data?

All forms of media are full of graphical representations of data and different kinds of statistical claims, all of which can be used to motivate discussion of the message being conveyed and the arguments being presented in the data.

NEXT STEPS

Changing School Mathematics

Deciding on the content for school mathematics is an initial step in the needed change process. So that the next steps proceed in harmony with the Standards, both the nature of the needed changes and the implied strategy for change should be understood. We are convinced, given the overwhelmingly positive response to the *Working Draft* of the *Standards*, that there are hundreds of teachers and other mathematics educators eager to bring about changes in school mathematics. In fact, we are optimistic that such changes can and will be accomplished.

Needed Next Steps

Curriculum Development. The Standards are a framework for curriculum development. However, there is no scope and sequence chart, nor is there a listing of topics by specific grade level. Although a coherent network of relationships exists among the identified content topics, multiple paths are available throughout this network. What we have done is to identify the key elements, or nodes, of the network to be included in a quality mathematics curriculum.

Textbooks and Other Materials. While we are aware that the curriculum program in many schools is geared to their textbooks, we expect the *Standards* to be used as criteria for measuring text content.

Tests. Tests have an influence on what actually gets taught in a classroom, especially in urban areas where teachers know that the test results will be used, rightly or wrongly, as an evaluation of *them*. New tests must be developed to assess problem solving, reasoning, etc., in a valid way to ensure that these topics are taught in *all* classrooms.

Instruction. The spirit and vision of the *Standards* cannot be achieved if instruction is inconsistent with the underlying philosophy they encompass. When specifying the content for a quality mathematics program, it is impossible not to address the accompanying instructional conditions. Thus, the elaboration of each standard deliberately contains implications for instruction and includes expectations about teacher actions such as the use of a variety of sequences, grouping procedures, instructional strategies, and techniques for evaluation.

Teacher Inservice. While we are confident that many teachers are now prepared and ready to teach the kind of mathematics program outlined in the *Standards*, many other teachers will need and demand additional training or refresher courses. These programs need to be developed in collaboration with the teachers.

Teacher Education. Prospective teachers must be taught in a manner similar to how they are to teach--explore, conjecture, communicate, reason, and so forth. Colleges of education and mathematical sciences departments should reconsider their teacher preparation programs in light of these curriculum and evaluation criteria.

Technology. Throughout each standard, we have assumed that appropriate technology would be available for use in classroom instruction. Calculators, computers, courseware, and manipulative materials are necessary for good mathematics instruction; the teacher can no longer rely solely on a blackboard, chalk, paper, pencils, and a text.

Differential Student Ability. The consequences of dealing with students with different talents, achievements, and interests has led to such practices as grouping, tracking, and special programs for gifted or handicapped students who need and deserve special attention. However, we believe that *all* students can benefit from an opportunity to study the core curriculum specified in the *Standards*.

Equity. As a pluralistic, democratic society, we cannot continue to discourage women and minority students from the study of mathematics. We believe that current tracking procedures often are inequitable and we challenge all to change current practice by developing instructional activities and programs to directly address this issue.

Working Conditions. In too many schools, teachers will find it difficult to teach the mathematical topics or create the instructional environments envisioned in these *Standards* because of local constraints such as directives about chapters or pages to cover, time for instruction, and tests. In particular, in many grades too little time is spent on mathematics instruction. Teachers and students should spend an hour a day on mathematics at all grades, as well as take advantage of the many opportunities to connect mathematics with other school subjects.

Research. The *Standards* are based on a set of values (philosophical positions) about mathematics for students, and the way instruction should proceed. These values not only are consistent with current research findings but also establish a new research agenda. In the redesign of school mathematics, much careful research is needed.

Summary

The National Council of Teachers of Mathematics has created a vision about:

- mathematical power for all in a technological society;
- mathematics as something one does--solve problems, communicate, reason;
- a curriculum for all which includes a broad range of content, a variety of contexts, and deliberate connections;
- the learning of mathematics as an active, constructive process;
- instruction based on problem situations;
- evaluation as a means of improving instruction, learning, and programs.

Keeping these points in mind, collectively we have a rare opportunity to provide the kind of leadership that will make real, substantive changes in school mathematics. These changes will ensure that all students possess both a suitable and a sufficient mathematical background to be productive citizens in the next century.

Mr. **Walgren**. Thank you very much, Mr. Coes. We appreciate that.

We will turn to Ms. Mosier.

STATEMENT OF JO ANN MOSIER, FAIRDALE HIGH SCHOOL, FAIRDALE, KY

Ms. **Mosier**. Mr. Chairman and members of the committee, we very much appreciate this opportunity to listen to the people that I feel very strongly can make meaningful and lasting change in today's schools.

We can talk about all the peripheral groups. There has been a decade of research and reports about what needs to be done in mathematics and science education, and, people, it is time for us to move, and we are the ones that are going to have to do it.

We have heard today three main strains in every one of the reports that have addressed your committee. They have talked about content. Teachers need to be updated in content.

The National Council of Teachers of Mathematics have standards that will be published in final draft form this spring that address a K through 12 curriculum in mathematics that is extremely pertinent to the needs of today's technology of the twenty-first century.

NSF can help with these kinds of endeavors through software, through training, through technology, data projection panels for all mathematics and science teachers, and we need training, and as we are trained we must continue to network with these people to support teachers as they design, as they implement, as they evaluate because the school that I come from—and we call our school a real school, and I bet not too many people here know where Fairdale, Kentucky is, and I want you to know. I am going to give you a landmark, and it is the Kentucky Derby. We are five miles from Churchill Downs, and we deal in our school with what we call real kids.

Fifty-eight percent of our population is at risk and, defined by our school district, which is Jefferson County Public Schools, that means that one to two—that they are one to two years behind mathematics and reading at their level, and we service at our school inner city students to rural settings, and we have all the stuff in between. So what we must do—what works for Mr. Coes might not work for our students at Fairdale High School. But I teach in an environment—and this is another strain we have heard today—where we are empowered to design curricula to meet the needs of our students.

If you look at my testimony that I wrote, we are working with general math students that—this is abhorrent, but I want you to know that there is a third grade level of mathematics that can barely do anything in mathematics, much less do any applications or do any high powered thinking. But we are working with a program from Michigan State University where we do a lot of modeling, language development, and game playing, and we develop the concepts that way, and we have had remarkable success. But we would not have that success if we didn't have the training, if we didn't have the networking, and that is so important and that is critical to what we are about today.

You must support teachers as they go about this design of a new curriculum, and we have had the training, we have had the networking, and we have had some remarkable successes. But our administration supports us in what we do. We have a principal that is an instructional facilitator. She says you are the ones that know what needs to be done in the classroom, what can we do to help.

So we must empower teachers, but I truly believe that as we empower teachers, we empower students. I have this list on my classroom. It is called "Mathematical Empowerment. Can you listen? Can you read with comprehension? Can you talk to me about mathematics? Do you have an attitude about mathematics it is extremely important?"

And all of those strains come from what the National Council of Teachers of Mathematics is talking about, and I think, Mr. Coes, did you not say that they have a copy of those standards?

Mr. Coes. Yes, it has been attached to my testimony.

Ms. Mosier. Okay.

And then the third strain that we have heard today, too, is pedagogy. It is difficult in the mathematics classroom to measure how effective have I been with what I do today. Lots of times I won't see the rewards of what I have done until 10 years down the line.

In fact, the other day I was in the drugstore and this pharmacist stuck his head over the counter and in a very loud voice said, "I know you, I had you in mathematics way back when, you made a difference in my life."

We are not like the surgeon that takes out the tumor in a person's stomach and I know immediately that person is going to be cured. That is not true. But I don't know if I am going to have immediate success.

But through the Woodrow Wilson Institute that I attended this past summer, where we learned about applied mathematics and technology, I have done some attitudinal change in my students. Those are the kinds of things I can perceive and evaluate immediately. That is attitudinal changes.

It is difficult when you go into a classroom and you tell parents and teachers that we are going to read and we are going to write in the mathematics classroom. Oh, no, not in mathematics. We have got to do some connecting. Mathematics does not stand alone, and teachers must be trained in how to integrate all of the fields into our discipline, and we do a lot of interdisciplinary units at our school and we do some cooperative learning, but we need training.

But what I am driving at is that research clearly states that no longer can the teacher stand at the board, be the imparter of knowledge, and have the students to imitate what we have done and to continue to think that they have developed and they are developing their own knowledge base. It is not working. But we need training on those pedagogies, and we need help.

No longer can we do that. What we are going to have to do is we have to ask probing questions. What if? What if I did it this way? Tell me another way to do it. And my students had a really tough with that. In fact, to quote one of my seniors in the fall in a pre-cal class, he said, "You know, Mrs. Mosier, if you would just stop what you are doing and tell me the answer, we could get this lesson on."

We can't do that any longer, and when so many of the teachers in the classroom do it, we become the flag bearers and the pioneers.

We need help. We need help from textbook people. We need help from NSF. Give us money. Train us. Let us go out and train other teachers.

I have established for myself my own comfort zone. I know what works for me. I can take the stuff from Michigan State, I can take the stuff from NSF and Woodrow Wilson, but no matter what, I have to work through it myself, and that takes time, it takes energy, and there aren't many rewards in our profession that tells me that I use three hours every day researching and developing new curricula. I don't have a lot of perks other than my own sense of inner pride.

Just like Dr. Saltman, I love to teach, but please help me.

This October, when we were given the awards for the Presidential Awards, I have never felt so important in my life. I really didn't believe that this happened to real teachers.

One recommendation I give to this committee, don't stop with those awards.

I felt so energized when I came back. I thought, you know, I really am important, I really am making a difference, but I would like to see awards given to elementary and middle school teachers in the area of math and science. Encourage those people. Let them know that math and science can be real and fun and exciting.

One more thing I would like to share with you about one of our big old football players that said before a national telecast—he says, "If you have a message to send to the nation, to all the mathematics teachers in the nation, what would you send them?" He said, "Tell those teachers not to stand at the blackboard any more and tell me all the answers. Give me credibility. I am smart. Let me try to figure out the answers myself."

But we need help. We need training. We need support. We need network. We need computers. We need technology.

I went out with grant money and bought graphic calculators. They are the most wonderful $60 instruments you have ever seen in your life. In a matter of split seconds, we can graph any function you give me, and the kids go, ooh, ah, what is happening? What would happen if I changed this? What would happen if I did that?

But we need the money to buy it. Help us.

[The complete prepared statement of Ms. Mosier follows:]

TESTIMONY
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SUBMITTED TO THE
UNITED STATES HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY

MARCH 9, 1989

I. HOW EFFECTIVE IS THE CURRENT MATHEMATICS CURRICULUM THAT YOU USE AND WHAT PROBLEMS ARISE IN INTRODUCING NEW CURRICULA?

*****

Innovative curriculum can be successfully implemented at a local school if focused training is available to the teachers. It must be valued, designed, and nourished by both local teachers and administrators as well as appropriate district personnel and the board of education. The training/implementation must value the teachers as professionals allowing time in their busy schedules to receive the training and to become responsible for their own professional commitment to the process and product. The following narrative of the success story at Fairdale High School (FHS) seeks to explain how innovation has helped restructure and refocus the curricula at FHS. Through a series of diverse activities described in this narrative, FHS has been able to make exciting progress.

Current mathematics curricula at FHS seem to be adequate for some students; however, we have continued as a staff to develop programs and curricula that best suit the needs of more of the students. Since 1986, FHS has been in a massive restructuring effort to design curricula that develops self-confidence and success for students as well as foster academic achievement. FHS has a diverse student population that comes from both rural and inner city settings. Fifty-eight percent of the student body is described as being "at risk" because they are one to two years below grade level in reading and mathematics.

**

One of the major efforts at FHS has been in the teaching of general mathematics. In Fundamental Mathematics (9th and 10th graders below grade level), we have been using materials that were developed through Michigan State University, titled the MIDDLE SCHOOL MATHEMATICS PROJECTS. The materials were researched and tested in the classroom by middle and high school teachers. Our focused training involved four teachers from FHS, along with eleven other Jefferson County Public School (JCPS) teachers and was funded by Title II funds. In this program, the emphasis is on concept development through modeling, language, and game playing.

The first year we used the materials, we saw an average gain of proficiency skills of 2.6 years with a range of 1.6 to 4.6 years. The increase in Kentucky Essential Skills Test (KEST) percentiles was equally impressive. The average percentile gain of reported scores was 21 with a range of negative 4 to positive 48. Our school was recognized by JCPS as having excellent achievement on the KEST in the area of "Grade 9 Math" for 1987. A significant variable in the class design was low class size, and we truly believe that it was a contributing factor to the large gains.

This is an issue on which not all administrators are willing to cooperate. This ambivalence about class size combined with staffing constraints often leads to unwieldy class size. Now we are in the third year of using the materials and we continue to report steady gains. This year, two of the teachers team with a special education teacher which provide us with a wider range of trained professionals in using the materials to foster confidence and mathematical achievement.

FHS knows the program is effective. However, the time and materials needed to implement the teaching strategies can be overwhelming. For this reason, many teachers in the training have stopped using the strategies. It is much easier to open the book, talk a little bit and say to the students,

> "Turn to page 93, and work the first 30 problems.
> Be quiet - do not make noise."

This is disturbing when contrasted to the following quote from the recent report EVERYBODY COUNTS, it is stated that . . .

> "Research on learning shows that most students cannot learn mathematics effectively by only listening and imitating; most teachers teach mathematics just that way."

Society does not usually reward teachers for innovative curriculum and working three hours extra each day to coordinate and researach a new program. The perks come from student success, peer assistance, administrators who encourage and support, and each teacher's own sense of inner pride.

Thus, the reasons for success at FHS are summarized as follows:

1) A support system of compatible trained teachers
2) A supportive local administration
3) District-wide training opportunities. The JCPS system is committed to "maximizing student success in a supportive environment."
4) A sensitive, creative mathematics specialist who searches for effective, innovative curricula for teachers to value and implement
5) Small class size (between 10 and 20)

Because of our newly developed expertise, we have already trained ten middle and ten elementary teachers and plan to train more again this summer. The significance of this training is that it is done by teachers who have used the materials with "real students" and they can relate to others what is effective and what produces maximum success.

We continue to encourage our school system to retrain more middle school teachers to use these materials and strategies because this will allow high schools to teach more students who are on grade level. FHS would ultimately like to retire from the remediation, retraining operation.

**

Another curriculum endeavor that we introduced at FHS is a Mathematics/English Seminar which started four years ago at 7 o'clock each morning as a college entrance exam prep session for volunteer students. Today, this effort is designed as a seminar for seniors and a computer literacy course for juniors for first semester. For second semester, the groups are interchanged. In the seminar, test taking skills are reviewed and applied to entrance exams in the area of mathematics and English. I team teach this course with an English specialist and next year we will incorporate a reading specialist. The computer course is taught by the business department where word processing, data base, and spread sheets are taught. In defiance of research, students have reported not only increased scores on the ACT, but some have doubled their scores in mathematics or English.

Again - a proven success story and problems arose with the state and school district over credit, titles, and population served. A supportive administration and counseling staff worked through the semantics and with sound teaching objectives, we have designed, implemented, and improved curricula to best meet the needs of students.

There was no formal training in this endeavor - only the experience of one teacher whose voice was heard concerning low ACT scores that did not match their high G.P.A.'s.

It is our hope to train more of FHS's staff with some of the strategies we use to better enable all our students to retain and to construct their own knowledge base. The areas of concentration will be spiral learning, study skills, reading comprehension, and writing skills.

We continue to experience that students are best served in an environment where the teaching professionals are empowered to design curricula to best fit the needs of the students they serve. This empowerment of teachers will in turn empower students with self-confidence and their own knowledge base.

**

Another retraining experience for me was participating in a Woodrow Wilson National Fellowship Foundation Institute (WWNFFI) on Technology and the Mathematics Curriculum. The content was primarily at the precalculus level. The sessions in this training were stimulating and valuable, again because the training was given by teachers who had tried the techniques with "real students." The point is that curricular endeavors can only be successful when they are researched, designed, implemented, and evaluated by teachers in the classroom through a collaborative effort many times with universities and/or businesses.

In the institute, we were introduced to strategies on incorporating technology (computers, graphic calculators) into the precalculus curriculum. Communications (written and oral), problem solving, and real world applications were stressed. The networking with other teachers was also valuable and support has been present the whole year. The University of Louisville (U of L) supported the training in collaboration with JCPS, offering both university credit or inservice training in addition to a stipend. These kinds of incentives are extremely attractive to the classroom teacher and certainly invite participation.

The problems in implementing the new strategies have been:

1) Convincing parents and students that reading with comprehension and oral and written communication are an integral part of a mathematics course.
2) Developing self-confidence in students as the focus of instruction changes from "explanation and examples given via teacher" to discovery techniques where the student is asked, "Why? Tell me another way. What if..? Can you estimate a reasonable answer? You correct it. Take a risk!" The student becomes the worker, and he is responsible for his/her own learning. (Ideas, from Ted Sizer's Coalition of Essential Schools).

   (A student's frustration was so appropriately expressed at the beginning of the year when he said, "If you would only tell me the answer - we could go on.")

3) Encouraging faculty members to incorporate scientific and graphic calculators, computers, and data projection panels into their instructional plan. We must continue to allow all students to experience mathematics as it emerges from, and is applied to the real world. What a tool the technology is to permit all the investigation to occur!! It is no longer appropriate or sound pedagogy to complete pages of irrelevant computation. Research is stating that students will not become experts through explanations or readily solved examples.

The student must investigate, ponder, and conquer the knowledge for him/herself (Blais). EVERYBODY COUNTS reports that:

> "A mathematics curriculum that emphasizes computation and rules is like a writing curriculum that emphasizes grammar and spelling; emphasis on mechanics of mathematics not only inhibits learning, but also leads to widespread misconceptions among the public concerning strengths and limitations of mathematical methods."

To investigate mathematics via technology requires a financial commitment from local school districts. Again, the JCPS system supports the use of technology and the training of teachers in the use of that technology. Through a collaborative effort with parents and business groups, all schools in the JCPS system have a computer lab.

FHS has the following computer labs: Tandy's for the mathematics department, IBM's for the business department, MacIntosh's for writing across the curriculum, and Apple IIe's in a mathematics classroom to enhance instruction. To assure optimal usage of these labs requires a coordinator with training and software knowledge.

In conclusion, innovative curricular and mathematics reform will not occur, no matter how much research and planning the peripheral groups support, unless the mathematics teacher is committed to the need and the process. The only person that can bring meaningful and lasting change is the teacher.

II. HAVE YOU USED ANY NEW CURRICULAR MATERIALS DEVELOPED THROUGH NSF SUPPORT?

The new curricular materials that I have used through NSF support are:

- COMAP - The Newsletter of the Consortium for Mathematics and Its Applications
- Woodrow Wilson National Fellowship Foundation - National Science and Mathematics Leadership Program Materials
- Workshops and materials so generously donated through the Presidential Award for Excellence in Mathematics and Science Teaching (PAEMST), 1988.
- Introduction to College Mathematics, developed by the Mathematics Department of the North Carolina School of Science and Mathematics. The materials are funded by the Carnegie Corporation and are in response to reports by the NSF to begin preparing students for their lives in the 21st century. The course emphasizes a mathematics of real-world application with integrated technology.

III. IN WHAT WAYS DID YOUR PARTICIPATION IN A TEACHER TRAINING INSTITUTE CONTRIBUTE TO YOUR EFFECTIVENESS AS A TEACHER?

The NSF teacher training institutes that I have attended have greatly increased my repertoire of knowledge, provided a network of collegial support, and revived my teaching spirit, not to discount the opportunity to earn college credit and to receive a stipend at the same time. The institutes also give me an opportunity to think through my teaching approaches, and I continually review better ways to do things.

In the mid 60's, I was trained in advanced techniques of algebra and geometry, and in the early 70's, we pioneered the teaching of high school computer programming. We had one computer terminal per JCPS (in a closet), and we coupled into the U of L via telephone. Many of the first students I trained went into computer programming and engineering as a career. We all know that technology has certainly come a long way, but the frightening aspect of that group of trained teachers is that most have retired or will within the next decade.

This summer I participated in the WWNFFI that is partially funded by NSF. We are using the materials from the institute through technology, applications, and writing.

This fall I had the great pleasure of being selected the PAEMST for Kentucky. The accolades, collegial support, and workshops provided to us through NSF have been encouraging and far beyond my wildest dreams. The training and rewarding of mathematics and science educators must be a continued focus and priority of NSF.

IV. WERE YOU ABLE TO TRANSFER NEW TEACHING SKILLS OR CURRICULAR MATERIALS ACQUIRED FROM THE INSTITUTE TO YOUR COLLEAGUES IN YOUR SCHOOL?

The transfer of new teaching skills or curricular materials from the institute is shared with colleagues in my school and other schools. It is always rewarding to learn new techniques, develop them with my students within my own comfort zone, and then to share them with my colleagues. New experiences and techniques can be shared in JCPS through inservice opportunities where teachers are invited to share with other teachers.

Kentucky Educational Television (KET) recently filmed a lesson on "slope" at FHS to exemplify teaching strategies that correlate with the NCTM Standards. The lesson, from the Mathematics Teacher, used the discovery approach before the algorithm was presented. Computers and graphic calculators were used to facilitate the discovery. The communication that occurred amongst the students as they pondered and established their own knowledge base on to what "the slope of a line" means, was totally exemplary of "students at work, doing mathematics." The lesson is part of a documentary that will be offered to school districts nationwide. It will be presented in Orlando this spring at the NCTM conference. The strategies and approaches, software and technology were curricular suggestions that were presented at WWNFFI.

V. WHAT ARE YOUR VIEWS ON HOW TO IMPROVE SCIENCE AND MATHEMATICS INSTRUCTION IN THE NATION'S SCHOOLS?

As we view improvements in mathematics and science instruction in the nation's schools, we must all realize there are "no quick fixes or answers." Various groups have been studying mathematics and science reform for nearly a decade, and it is time for action. The following issues are points of consideration.

** Increase teacher training opportunities which:
  a) update mathematics and science teachers in mathematical and science content. The NSF academic yearly institutes of the sixties may need to be revived.
  b) train teachers in the effective use of technology in the classroom (graphic and scientific calculators, computers, and data display panels). Every mathematics and science teacher should have at least one computer and a data projection panel for their classroom. This is in addition to the programming lab.
  c) develop and support research based effective methodologies such as modeling, communication (oral and written), problem solving, and the active involvement of students "doing mathematics."

** Collaborate with the universities concerning preteacher training to provide scholarships to capable students willing to major in mathematics or science education.

** Assist universities and local school districts to collaboratively develop effective programs that train mathematics and science specialists for elementary and middle schools. Concept development and positive attitudes would increase while mathematics anxiety should decrease.

We must promote number sense in our youngsters and allow them to explore the "magic" of mathematics at an early age. Allow them to experience mathematics as a tool to solve real world phenomena. The only way students can establish a comfortable knowledge base with respect to mathematics and science is to have knowledgeable and experienced teachers leading the instruction, thus the need for elementary and middle school mathematics and science majors.

** Encourage local schools to create an environment where teachers are empowered to design curricula that best fits the needs of their student population. The learning environment should be an atmosphere of academic achievement with self-confident, successful students in a teacher controlled instructional process. Lawmakers and local school districts can facilitate this autonomy of local schools through support of principals who act as instructional leaders/facilitators.

a) Reward school-based efforts by creative and successful science and mathematics teachers and set up fellowships for them to work with other teachers for one year to foster and spread their success.

b) Have lead mathematics and science teachers in each school who teach part of the day and consult with other teachers for the remainder of the day. They should be responsible for organizing departmental reforms, coordinating research and technology, and aiding colleagues in effective pedagogies. All professionals need to stop protecting "turf" and allow true reform to occur that has student success and academic achievement as the optimum measure.

c) Allow schools flexibility in scheduling the school day/year. Allow students time for independent, long range projects, interdisciplinary study, and to establish their own knowledge base.
Teachers also need more time - lengthen the school year to allow for research, curricular development, training, goal setting, parent/student conferences, collegial sharing and observations.

** Interaction between the experts serving on various boards/task forces who have been researching mathematics and science educational reform and local school districts/teachers should occur to facilitate and advise any restructuring efforts. Investigate pedagogies and curricula that best meet the needs of the students in that area. School boards must commit per diem monies to fund this endeavor.

** The program of mathematical and science study needs to be a continuous (K-12) curricula that is demanding but supportive, and meets the needs and demands of today's technological world. The mathematics and science must be rigorous and substantial.

In this rigor, number sense for our youngsters must be developed. The literacy of numbers is critical to the 21st century and leads to problem solving, higher order thinking skills, modeling, and decision making. Today's society continues to bombard us with a proliferation of data. Mathematical curricular reforms must be sensitive to teaching students how to organize, manipulate, discuss, and make inferences from that data. To develop these skills, the NCTM standards purport an emphasis on probability and statistics and discrete mathematics. Obviously, technology is invaluable in storing and manipulating the data. There is a need for training and materials in light of this curricular emphasis.

** Mathematics textbook publishers must write textbooks to reflect the changes in content and emphases in K-12 mathematics, supported in the NCTM Standards. Kentucky has delayed mathematics textbook adoptions for one year in hopes that the publishers will provide texts that enhance the pedagogies and curricula recommended in the Standards. The delay occurred because of recommendations by mathematics teachers, supervisors, and administrators.

** Begin an intensive national Pro-Education campaign aimed at all populations (Ashland Oils efforts are exemplary). Massive education of parents to lessen mathematical anxiety and to increase problem solving skills in the home is necessary. The PTA is a perfect forum. Successful mathematics and science teachers/parents could lend practical advise to the audiences. The time of, "I was never any good at math" should no longer be worthy of a "merit badge."

** Continue to fund the PAEMST but expand the awards to encompass the elementary and middle school levels in mathematics and science. Do not allow the President to skip the awards ceremony to honor the Los Angeles Dodgers or other such sports heroes. Create a system to authentically honor education heroes.

** Mathematics and science teachers must be an integral part of any improvement efforts. It is our professional obligation to continue to read, discuss, and act on research that address mathematical educational needs. Our pedagogical approaches must be redesigned to increase understanding and retention of mathematical concepts and processes. The mathematics that we teach must be updated to address the needs of the 21st century. Changes in content and emphases is critical (NCTM Standards). As stated before, only the teacher can bring meaningful and lasting change.

BIBLIOGRAPHY

Blais, Donald M. "Constructivism - A Rheoretical Revolution for Algebra." Mathematics Teacher. (November, 1988) 625-631.

National Research Council. Everybody Counts, A Report to the Nation on the Future of Mathematics Education. Washington, D.C.,: National Academy Press, 1989.

National Council of Teachers of Mathematics. Curriculum Evaluation Standards for School Mathematics. (Draft). Virginia: NCTM, 1987.

Gustafson, Deborah Ann Thompson. "Skiing the Slopes." Mathematics Teacher, (December, 1987), 733-735.

PROFESSIONAL EXPERIENCE

Mrs. JoAnn Mosier
Fairdale High School
1001 Fairdale Road
Fairdale, KY 40118
502-454-8248
Jefferson County Public Schools
Louisville, KY 40232-4020

1426 Rosewood Avenue
Louisville, KY 40204
502-456-1505

Teaching Experience

*	Fairdale High School (Mathematics Teacher)	August, 1985 - Present
*	University of Louisville (Lecturer in Mathematics)	1976 - 1985
	Indiana University Southeast	1978 - 1979, 1981
	Spalding University	1985
*	St. Agnes Academy, Fern Creek High School Thomas Jefferson High School	1964 - 1975

EDUCATIONAL RELATED EXPERIENCE

*	Mathematics Tutor (self-employed)	1975 - present
*	Curriculum Writer (Heath Publishers, Addison Wesley, Harcourt, Brace, Jovanovich, JCPS)	1987 - present
*	Conference Presenter (Kentucky Educational Computer Conference, Ohio Council of Teachers of Mathematics Kentucky Council of Teachers of Mathematics Ohio Valley Educational Cooperative Leadership Conference, Kentucky Association of School Administrators	1986 - 1987
*	Inservice Presenter (Greater Louisville Council of Teachers of Mathematics, FHS Mathematics Department, JCPS, Marion/Washington County, Fort Knox/Elizabethtown Counties, Louisville Catholic Archdiocesan Teachers	1986 - present
*	Mathematics Team Sponsor and Kentucky High School Math Contest, FHS	1985 - present
*	Gheens Professional Development Academy Faculty Representative, Steering Committee Member	1987 - present
*	KET Planning Committee to design strategies that exemplify NCTM Standards	1989
*	Merit & Evaluation Team for the Mathematics Department of Fayette County Schools	1989

PROFESSIONAL TRAINING

* University of Louisville (Rank I, Certified in Supervision,	1980
Master of Arts, Mathematics	1971
* Spalding University (Bachelor of Arts, Mathematics)	1964

PROFESSIONAL ORGANIZATIONS

- National, Kentucky, and Greater Louisville Councils of Teachers of Mathematics
- The Mathematical Association of America
- National, Kentucky, Jefferson County Education Association
- Delta Kappa Gamma, Sigma Chapter

HONORS AND AWARDS

* National Science Foundation Grant Recipient	1966, 1972
* Kentucky State Teacher	1971
* General Electric Foundation's Math Teachers Recognition Program, $1,000 Grant	1987
* Bellarmine College Leadership Education Participant	1987 - 1988
* NEA Symposium on School Based Reform Participant	1987
* Greater Louisville Council of Teachers of Mathematics "Excellence in Teaching Mathematics" Award	1988
* Kentucky Presidential Awardee for Excellence in Mathematics and Science Teaching (NSF), $7,500	1988

OTHER ACTIVITIES

* Kentucky Easter Seal Hearing and Speech Board	1980 - 1985
* Tyler Park Neighborhood Association Board	1983 - 1985
* St. Agnes Elementary School Board Vice-Chairperson	1984 - 1987
* St. Agnes Elementary School Math Counts Coach	1988
* PTA presenter: St. James, St. Agnes, Our Lady of Lourdes	1983 - 1984

PERSONAL

Husband, Rudy Mosier, Band Director in Oldham County School System
Children, two daughters, Holly, age 14, Kristi, age 12

Mr. **Walgren**. Well, thank you very much, both of you, for being what you are, and the awards that you received from the Presidential level certainly were well-deserved, and we hope we can create that kind of enthusiasm elsewhere as well.

Mrs. Keranen.

STATEMENT OF KATHRYN KERANEN, COOPER INTERMEDIATE SCHOOL, McLEAN, VA

Mrs. **Keranen**. I took a course last year at the University of Maryland that was sponsored by the National Science Foundation, and it was on microcomputer-based laboratories, and I would just like to take a couple of minutes to tell you what effect this had on my teaching.

I went over there and I started this course, and by the first day I knew I was in a situation that I hadn't been in in about 23 years, and that was I was taking a course that was going to be about science. I had had to take so many courses that had nothing to do with science that I thought science was something I hallucinated about in college. [Laughter.]

I mean, I thought this man, he knows what he is talking about, he is excited. He was a specialist in his field. As most physics teachers, he was all excited about this heat energy, and as I listened to him, something about it inspired me. I came back to my classroom, and I wasn't worried about color-coordinated bulletin boards and sitting the children in groups and looking to the right and looking to the left. I thought, I am supposed to be teaching science.

I came back to Fairfax County, and they allowed us like two weeks to use what we had learned and develop new curriculum just for Fairfax County. After we did this, I submitted that book to these people at the University of Maryland, and they must have taken hours because they went over each lab and gave us technical assistance.

I don't know if any of you know it or not, but in the classroom if you don't know something and you ask the teacher next door and they don't know it, you just go, well, I am not going to teach that because I don't know it. And that is what happens.

But these people were giving us technical assistance about stuff that we didn't know, and they were saying, well, you should revise this and do it this way and do it this way.

Plus the fact Fairfax County had given us a lot of new equipment, and I mean that sounds wonderful, but you take a 45-year-old woman and you set her in the room with eight computers and then you give her eight new pieces of software and they have light sensors and pH meters, and then you say, now you get all this to work. That is hard, and I have called these people up time and time again, and they have come to my aid to fix this equipment.

After we wrote this curriculum for Fairfax County, we gave several in-services with people in the county which involved them in the project. The National Science Foundation instructors came to all these in-services, or most of them.

The summer workshop dealt mostly with heat and temperature probes. But the little bit of training I got there enabled me to go on. I mean, I have done voltmeters, pH meters, sound sensors. I am now involved with this strain gauge. It opened a whole new world for me.

I went back to my school. I set up a computer lab. Everything that they taught me every teacher in my school knows now, and all the children in my school are going through this lab. So you have to say this kind of has a ricochet effect.

I have been reading in the paper and I know science and math have come under a lot of criticism, and I truly believe that the way education is going today we are going to raise a generation of children. They are going to feel wonderful about themselves. They are not going to know anything, but they are going to feel really good. You know, I just keep thinking something is not right here.

So the last part of my testimony probably has to do not only with motivation, but enthusiasm, because the one thing you can give to a teacher—I don't care what else you give—if you are excited about something you can get your children excited, and that is what this summer did for me. The people that taught this was excited. It got me excited, and I in turn have got my school and my county excited about the curriculum.

[The complete prepared statement of Mrs. Keranen follows:]

Testimony: Kathryn Keranen
Committee on Science, Space, and Technology

Purpose: To review National Science Foundation programs that support development of curricular materials for precollege science and mathematics instructions and programs that provide in-service teacher training.

During the summer of 1988, under a middle school probeware project supported by a grant from NSF, TPE 8751744, and taught by Dr. John Layman and Dr. Joe Krajcik, training workshops using HRM's Heat and Temperature Microcomputer Based Laboratories (MBL) were conducted. These workshops provided selected eighth grade teachers with knowledge and experience using microcomputers in science laboratories. The following testimony is my experience gained from participating in this program and the resulting impact on my individual school and my school system.

Before I participated in the MBL workshop, my experience with computers and interfaces had been three days' inservice training by Fairfax County Public Schools and individual experimentation. My participation in the MBL workshop provided me with an opportunity that I had not had in my twenty three years of teaching. It was, first of all, one of the few courses in pure science in which I had been involved. Teachers are required to take numerous courses that have little or nothing to do with science. Science is such an ever-changing field that it is important to focus on new developments as well as to refocus on the basic commitment to the scientific method. This MBL course was taught by a competent professor and specialist in the field of MBL. I went back to my classroom with increased scientific knowledge and not educational jargon on group work, and color coordinated bulletin boards. My teaching of science itself became revitalized, and my content was suddenly not stagnant.

After participating in the MBL course, Fairfax County gave the participating teachers time to develop labs using MBL that fit our specific curriculum in Fairfax County. The handbook we devised was read and corrections were made by the NSF professor. Technical assistance of this type is indispensable.

After writing a MBL lab book for Fairfax County teachers, my colleagues and I gave three inservices explaining MBL and helping teachers use them. Many of these workshops were attended by the NSF sponsor.

The summer workshop dealt mainly with HRM heat and temperature probes. However, the training I received with this probeware allowed me to be confident enough to explore other probeware and develop curricula to support the use of light sensors, sound meters, pH and voltmeters. I am currently investigating the use of strain gages with the voltmeter.

Upon returning to my own particular school, I established a science computer lab where experiments are done with the computer used to collect data. Support from Fairfax County Office of Instructional Technology and my own school administration enabled this to be accomplished. The five other teachers in my department also use the computer lab and my training has been transmitted to all of them.

Science and math have been under criticism lately because of the failure to produce superior test scores. I do not find this hard to believe and contribute this partly to a let down of pure science being required by both teachers and students. I hope in the trend to make all students "feel good about themselves" we don't raise a generation of children that do not know basic science.

The last part of my testimony has to do with the teacher as a motivator to learning. If I am to be the motivator for my students, I occasionally need to be motivated as well. Many teachers hear the same mundane things year after year after year...state your objective, conclude the lesson, group the children, vary your style. All of this is fine, but science in itself can be much more exciting if the teacher has a broad background of scientific knowledge. There has always been the debate about content versus teaching skills. An ideal situation is a good teacher with adequate content knowledge, while an unacceptable situation is a good teacher with little content knowledge. Many teachers do not have any further scientific training after they leave college. Though it may be true that teachers of eighth grade physical science do not need graudate courses in science to teach that curriculum they do, however, need updated and correct scientific information.

The National Science Foundation grant enabled me to gain new science knowledge, use my expertise to develop new curricula, and to introduce that curricula in my classroom, my school, and my county.

Mr. **Walgren**. Well, thank you very much for sharing those feelings with us, and I wish time would permit us to go further with it, but I think I have to turn to the last panel.

My reaction is, gee, I don't want to do this any more, I want to go do that, and so there is something that is very infectious about the way you are approaching these areas and the subject matter itself and what it means for people and how it fits in with what we want to do with life.

So I hope we can play a real role in giving you the resources to spread that as far as you possibly can. So thank you very much for being a resource to us.

Let me call then the last panel—Dr. Richard Atkinson, who you folks know is President of the American Association for the Advancement of Science and also the Chancellor at the University of California-San Diego.

Is that Dr. Saltman's place?

Dr. **Atkinson**. That is the same place.

Mr. **Walgren**. Same place, okay.

Dr. **Atkinson**. He is a member of the faculty.

Mr. **Walgren**. Professor Lynn Arthur Steen, the Chairman of the Council of Scientific Society Presidents; and Dr. Thomas Malone, the President of Sigma Xi.

Welcome, all, and I guess I don't feel quite as bad as some other hearings when people have had to sit through it and wait until the end because I have felt that all these witnesses have really energized us more than drained us. But I do apologize that we have gone on so long.

But in any event, we have time for you, and I would like to invite you to give your testimony in the order in which I introduced you to the record.

So please, Dr. Atkinson. It is good to see you again, and we are very pleased you are here.

STATEMENT OF DR. RICHARD C. ATKINSON, PRESIDENT, AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, AND CHANCELLOR, UNIVERSITY OF CALIFORNIA-SAN DIEGO, SAN DIEGO, CALIFORNIA

Dr. **Atkinson**. Mr. Chairman, I am going to be very brief. Let me say that when I saw the list of witnesses this morning I knew that we would be running late, and I actually thought about not showing up. [Laughter.]

But I really came this morning because I wanted to hear the other witnesses, and I was well-rewarded. It was a very exciting morning in terms of the sorts of comments and remarks that were made.

I am submitting for the record some remarks, rather detailed remarks on the three bills that are being considered, and I think those will be useful to the committee in reexamining those bills.

I would just make one remark that I have become something of an expert in the last few months on the whole issue of the shortfall in Ph.D.'s that we are going to be confronting as a nation, and one sees the numbers on that. That is another side to this whole problem that I think needs to be considered, the pipeline, the general issues of the quality of education for K through 12, but the impact that the shortage of PhD's will have by the turn of century is really quite dramatic.

Let me just say one thing then about the legislation that is being considered today, and I really want to focus just on your bill, Mr. Chairman.

As you know, I am extremely enthusiastic about this bill. My own particular view is that there is no solution to the problems we face. There is a whole range of things that have to be done, but one thing that has to be done is call attention to these matters, and what I like about your bill is the idea of the excitement, the identification of the scholars that would be given these awards.

The only comments I would want to add on your bill would be that I would like to see some name given to these fellows that would really give it national visibility. I don't know what that name should be—Congressional Fellows. I am not sure Walgren Fellows is quite the right now—but something that would give real national——

[Laughter.]

Dr. Atkinson [continuing]. Would give real national visibility to these fellows, and I want to be sure—I like the geographic distribution of two per district, but I want to be sure that these fellows are recognized among themselves on a national basis. So I think you need things like newsletters, subscriptions to Science, or the like, to tie these fellows together so that they will recognize the importance of what they are doing and will stay with the whole process.

I might really question whether NSF is the right group. I think NSF is the right place to fund this program, but I am not sure if NSF is the right agency to run the program. I think it might be much better if it were run outside of the government by the National Academy of Sciences or even by an organization like the AAAS because I think there is some care and feeding over time of fellows in the program that needs to be attended to.

The only last remark I will make is that I would hope this committee would use its relations with the various oversight committees that relate to the Office of Education to try to encourage a much broader base of activity in this area, and I think the legislation being proposed here, if it could be brought to the attention of some of the members of the House related to the Office of Education, it might work to broaden the base of the discussion that is going on, and I think that NSF plays an important role here but I think it is a mistake to believe that over the long haul NSF can do the job by itself that needs to be done. The Office of Education has to be involved in a very active way, and I would hope this committee might be a way of instigating some activity on that side of the——

Mr. Walgren. It is always hard for us jurisdictionally in the Congress, and particularly since this committee really has never had legislative authority in areas that affected the Department of Education, and we are somewhat limited.

I realize that the Department of Education—well, that the problem is so big that certainly they have to make a real contribution in where we want our whole educational system to go. I guess the question is whether this program, if it could be started—and thinking of the Congressional science and math scholars—even the President, to our real surprise but delight, singled that concept out, and it makes me feel that it is something that can be realistically talked about in this Congress, with the thought of actually implementing, and at that point then the question really comes whether the NSF is the right agency. Some agency, or some entity has to have the governmental responsibility, and perhaps in executing it, it could go beyond itself and incorporate broader societies that might be able to provide local people that would then be reinforcing of the track we hope these people will stay on.

Well, we can come back and talk about it.

Dr. **Atkinson**. Mr. Chairman, I only meant with regard to these three bills I think this is the right committee and NSF is the right agency.

Mr. **Walgren**. Yes.

Dr. **Atkinson**. I really meant with regard to the range of activities that are being discussed we should draw the Department of Education into that discussion.

[The complete prepared statement Dr. Atkinson follows:]

Statement by

RICHARD C. ATKINSON

President

American Association for the Advancement of Science

Before the

Subcommittee on Science, Research and Technology

Committee on Science, Space and Technology

U.S. House of Representatives

March 9, 1989

RICHARD C. ATKINSON

CHANCELLOR

UNIVERSITY OF CALIFORNIA, SAN DIEGO

Dr. Richard C. Atkinson is Chancellor, University of California at San Diego, and President of the American Association for the Advancement of Science. From 1975 to 1980 he served as Director of the National Science Foundation. As Director he had a wide range of responsibilities for science and technology at a national and international level, including membership on the United States-People's Republic of China Joint Commission on Science and Technology and the US-USSR Joint Commission. He was responsible for negotiating and signing the first memorandum of understanding in history between the People's Republic of China and the United States, an agreement for the exchange of scientists, scholars and students.

Prior to 1975, Dr. Atkinson was on the faculty of Stanford University for twenty years. He has been elected to membership in the National Academy of Sciences, American Philosophical Society, American Academy of Arts and Sciences, and Institute of Medicine. He has been awarded honorary Doctor of Science degrees by ten American universities, holds honorary memberships in several foreign societies and academies, and a mountain in Antarctica has been named in his honor.

INTRODUCTION

Mr. Chairman and Members of the Subcommittee:

Thank you for your invitation to testify at this timely hearing on the crisis in science and mathematics education and to comment on several bills under consideration by your subcommittee.

I am Richard Atkinson, Chancellor, the University of California at San Diego. However, today I am appearing as President of the American Association for the Advancement of Science (AAAS).

The AAAS is an organization of 133,000 scientists and engineers, and has 295 affiliates representing over 5 million members in various scientific, engineering and professional societies. AAAS publishes the journal Science, as well as policy documents addressing ethical, educational, economic and technical issues facing science and its related professions.

Underlying your consideration of science and mathematics education issues is a well-founded concern for the future of the human resource base for science and engineering. This is an issue of major concern within the AAAS, and indeed within the science and engineering communities as a whole. Many in these communities would say that the human infrastructure is the most serious science and technology policy issue we face today.

The long term prospects are dismal indeed. Fewer American youth are choosing careers in science and engineering. This is but one manifestation of what has become to be known as the "pipeline" problem. Lack-luster education in science and mathematics dampens interest and retards achievement. The effects are particularly devastating for young people from populations under-represented in the science and engineering professions. Among the consequences are:

- consistently low enrollments in high school physical sciences and advanced mathematics;
- declining numbers of college freshman majoring in technical subjects;
- and poor retention among those who begin college concentrating in a natural science.

THE DIMENSIONS OF THE PROBLEM

The pipeline has massive leaks: Too few technically talented young people make it from "grade school to grad school." The threat is real as the following statistics demonstrate.

- In 1987 only 42 percent of U.S.-granted Ph.D.'s in engineering were awarded to U.S. citizens.
- In 1985, only 5 percent of doctoral degrees in the physical sciences (physics, mathematics, and computer science) went to non-Asian minorities.
- By 1995 about 30 percent of the engineering faculty in U.S. universities will have retired and have to be replaced.
- In 1988 60 percent of American universities reported faculty shortages in computer science.

- In 1973, 11.5 percent of college freshman reported plans to major in the sciences; in 1988 that proportion had dropped to 5.8 percent of a smaller demographic cohort.

- An international comparison of mathematics and science achievement shows American youth lagging far behind their counterparts. Only 40 percent of American 13-year olds have the mathematical skills to solve two-step problems, this compared with 78 percent of their counterparts in Korea. Similarly, only 10 percent of American youth understand measurement and geometry, this compared with 40 percent of their counterparts in Korea.

- In 1985, the National Science Board reported that relatively large numbers of teachers were not certified to teach in the fields to which they were assigned.

- A 1986 National Science Teachers Association survey found that just 68 percent of science teachers in grades 7-9 met the association's science preparation standards. In grades 10-12 57 percent of the teachers met association standards.

- In an NSF-funded study of the American public's knowledge of science, Jon Miller found that only 6 percent of Americans are scientifically literate. For example, less than half of the people surveyed knew that the earth revolves around the sun once a year.

The Mathematical Sciences Education Board in its report, Everybody Counts, issued in January, urges a radical overhaul in the way mathematics is taught in the United States (kindergarten through college). The report also calls for closing the gap in mathematical achievement that separates the futures of a white, technologically-astute elite and a largely minority underclass that finds "economic and political power beyond reach."

The importance of mathematics to many careers, not just science and engineering, must be underscored. Noting that every year roughly half of the country's ninth graders leave the mathematical pipeline, the report states that "mathematics must become a pump rather than a filter in the pipeline of American education."

Two weeks ago AAAS issued its report, Science for All Americans. The report proposes sweeping changes in the goals, content, and methods of science education and calls for an unprecedented level of collaboration among scientists and educators as well as government, business, labor, and community leaders in an effort to effectively reform these crucial areas of education. It defines the common core of learning that all students should acquire as they proceed from kindergarten through high school to become scientifically literate adults.

Last fall the Task Force on Women, Minorities and the Handicapped in Science and Technology, which was established by Congress in Public Law 99-383, issued its interim report, Changing America: The New Face of Science and Engineering. The report points out the importance of women, minorities and the disabled groups in the face of a shrinking number of college age students and the changing make-up of the reservoir of technical talent.

A message common to all of these reports is the need for fundamental restructuring of science and mathematics education, a focus on the entire educational system, and the articulation of national goals.

I want to commend the Congress, and especially this Subcommittee, for the leadership it has shown in recognizing and addressing some serious science and education pipeline issues. It must be noted, however, that the policy response in the legislation we are considering today addresses only a small part of our total pipeline concerns. I want to offer some comments as to how these proposed pieces of legislation might be strengthened and how opportunities might be found to broaden their impact.

LEGISLATION UNDER CONSIDERATION

H.R. 996

Let me first comment on H.R. 996, "Congressional Scholarships for Science, Mathematics, and Engineering Act of 1989." Under this proposal the National Science Foundation is directed to establish a program for an annual, merit-based competition for selecting two students from each congressional district to receive four-year scholarships to study mathematics, science, or engineering.

Its specification of a female and male student from each district underscores the importance of bringing more talented young women into science and engineering. It further emphasizes that technical talent can be found in all of our communities. I do hope these awards carry with them the prestige associated with an appointment to a military academy -- sending the message that scientific talent is as important to our nation's strength as military compatibility. These scholarships are an important symbolic gesture to focus the attention of Members of Congress on the national importance of ensuring a steady flow of our most able young men and women to science and engineering careers.

These scholarships also could serve to highlight and underscore the larger challenges of financial support for higher education. We need to know how the shift from grant to loan-based support during the past decade has affected college attendance among disadvantaged minority students.

In order to broaden the pool of recipients and avoid having the scholarships awarded to those students who would receive many other awards, serious thought should be given to the selection process. The idea of basing the awards on potential and motivation is indeed a well-directed intention. Great care must be given to assure that this intent is carried out.

Under Section 3:

- Nominating Committees should include parents and business persons. They should also specifically include science and mathematics teachers in determining criteria for selection, including the applicant's potential and motivation. Further, the regional nominating committees should determine the criteria and process for deciding the applicant's potential and motivation, not the Director of NSF. A part of the process might include personal interviews of the applicants by members of the nominating committee.

- With respect to Eligibility and Maintaining Eligibility, admission and enrollment should be at institutions whose science, mathematics, or engineering programs are accredited, and where demonstrated and ongoing programs exist consistent with the goal of retaining a diverse population of students for science and engineering.

- Under "Maintaining Eligibility," as you consider this bill and similar legislation, you may also wish to give some thought to ways in which these scholarships might be used to leverage, for instance to encourage industry and institutions of higher learning to match the federal effort for these programs. For example, they might put up money for additional scholarships in each district, or at the state level, that would be incorporated into the same selection process, perhaps with some sort of tax incentives to the donors.

MR. SLAUGHTER'S BILL

The bill proposed by Mr. Slaughter establishes a "Science, Mathematics, and Research Technologies Scholarship Program." It is responsive to the OTA Report, "From Grade School to Grad

School," which suggests, as a short-term solution for addressing immediate needs within the pipeline, supporting students who have already demonstrated an interest and competence in science, mathematics, and engineering.

The bill also addresses the concept of leveraging federal dollars by requiring that scholarship monies be tied to public service, specifically service in the federal government or an associated organization. Special consideration should be given to service in organizations whose activities focus on education and the needs of under-represented youth. We would suggest that scholarship-for-service monies could be leveraged further to affect the pre-college end of the pipeline by including, as a service option, work with disadvantaged student populations. Such work could include, for example, teaching in pre-college math and science programs or cross-age tutoring. Of course, full-time mathematics or science teaching should fully satisfy the service requirement of the award.

A further comment on the service section of this bill relates to section 7(b) and the requirement that the Director of the NSF assist scholarship recipients to find employment. We suggest that this requirement might put an enormous burden on the NSF. Rather, it might be possible for the NSF to develop a list of federal agencies interested in attracting these young people, providing this information to the award recipients and encouraging them to explore these opportunities on their own.

MR. BOEHLERT'S BILL

Turning now to the bill proposed by Mr. Boehlert, "National Awards for Mathematics and Science Teaching Act of 1989," let me note that awards for undergraduates studying mathematics and science teaching have a track record of success in attracting top quality students to enter careers in teaching. Students from similar programs in the past have stayed on in the classroom far beyond their obligated terms of service, or have gone on to become leaders in mathematics and science education.

In response to the changing needs of a modern society, many vocational programs have become highly technical, offering curricula that provide a pathway into scientific and engineering careers for many students. Excellent technology teachers are needed for these new directions. For this reason, we recommend that the proposed bill be broadened and the wording throughout be changed to include mathematics, science, and technology teaching.

Other suggestions include:

(1) Under Section 3, Eligibility, enrollment should be at an institution whose science, mathematics, technology, or teacher education programs are accredited.

(2) A Section on Maintaining Eligibility should be added with wording that includes academic performance and course load.

(3) Under Section 4, Criteria for Selection, we suggest that a committee appointed at the college or university, consisting of mathematics, science, and technology

educators, and mathematicians and scientists, select the recipients.

(4) Under Section 5, Amount of Award, raise the amount to $5,000. Up to three awards should be available; the third award can be for work in a fifth year program for teacher certification.

(5) Replace Section 6 with the following: Service Obligation -- For every year of service, 25 percent of the total award will be forgiven. For every year in which the teacher serves as a Chapter 1 teacher, or as a teacher in a school in which at least half of the students qualify for the federal school lunch program, 50 percent of the total award will be forgiven. Each year following completion of certification, the Director must be notified that the teacher has completed a year of full-time teaching, until the complete award has been forgiven.

We suggest that the service in Chapter 1 programs should be part of an undergraduate teacher education program, which will help to draw faculty in teacher education institutes into the equation. You may also want to consider expanding the teaching requirement to "teaching at any level."

(6) Replace Section 7 with the following: If the individual is dismissed, withdraws, or -- with the exception of full-time graduate work, military duty, voluntary service, or other allowable circumstance -- if the individual does not enter

teaching within one year or leaves teaching, the recipient will have one year to repay the total balance of the award, plus interest.

CONCLUSIONS

Mr. Chairman, let me conclude my remarks by again expressing our appreciation to the Subcommittee for your deep concern about the state of U.S. science and mathematics education and its consequences for our country; for your continued support for science and mathematics education programs; and for your willingness to tackle the system's problems through your attention and legislative proposals.

We look forward to responding to your future proposals on other issues related to the pipeline. Please feel free to call on the AAAS if we can provide you with additional information, assist your work on other segments of the system, or further support your efforts to strengthen the human resource base of U.S. science and engineering and the education framework that shapes it.

American
Association
for the Advancement of
Science

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AAAS JOURNAL ISSUES REPORT CARD ON HIGH SCHOOL SCIENCE TEXTBOOKS

WASHINGTON, D.C. — A new report card on high school science textbooks is now available for teachers, school district administrators, and state education authorities involved in textbook selection and adoption.

Science Books & Films, the critical review journal published by the American Association for the Advancement of Science, has released its 4th annual report card on science textbooks. The journal's March/April issue evaluates 19 new and current high school science texts, including 4 just-released (1989 copyright) introductory biology texts and one just-released introductory chemistry text.

The 4 new biology texts, which will be among those considered for statewide adoption in such key states as Texas and California, are: Modern Biology, 6th ed. (Holt, Rinehart and Winston), which is the market leader in introductory high school biology texts; Biology (Harcourt Brace Jovanovich); Heath Biology, 2nd ed. (D.C. Heath); and Biology: The Living World, 2nd ed. (Prentice Hall).

Which textbooks are the best? The criteria used by the Science Books &

(MORE)

Films evaluators include content accuracy, currency, and scope; organization and coherence; comprehensibility to students; practicality and comprehensibility of labs; and treatment of the interrelatedness of science, technology, and society. "The textbooks that do the best job of providing quality in these areas -- as judged by SB&F evaluators (including high school teachers) -- are the best," stated Kathleen Johnston, SB&F Editor.

"SB&F remains the only periodical published by a scientific organization that consistently evaluates high school science texts," said Johnston, who initiated the project with special evaluations of biology texts in the May/June 1985 issue. Since then, SB&F has dedicated special issues to chemistry texts (May/June 1986) and physics texts (September/October 1986). An update on the texts in all three fields was issued in March/April 1988.

The current (March/April 1989) issue contains the most recent report card on texts, and it includes an index of the texts evaluated previously.

Science Books & Films regularly evaluates science trade books and educational films for children, junior and senior high school students, college students, teachers, science professionals, and lay adult audiences. Subscriptions (5 issues) are $32 per year; copies of the March/April issue, as well as the earlier textbook issues, are available for $7.00 each (plus $1.50 postage & handling per order) from: AAAS Marketing, 1333 H Street, NW, Washington, DC 20005.

* * *

ATTENTION EDITORS: Please feel free to call Kathleen Johnston at 202-326-6454 for a review copy of the March/April issue.

Mr. Walgren. I see.

We will come back in a second, but we will turn then to Professor Steen.

STATEMENT OF PROF. LYNN ARTHUR STEEN, CHAIRMAN, COUNCIL OF SCIENTIFIC SOCIETY PRESIDENTS, DEPARTMENT OF MATHEMATICS, ST. OLAF COLLEGE, NORTHFIELD, MI

Professor Steen. Thank you for the opportunity to appear, Mr. Chairman.

I am hear to represent the Council of Scientific Society Presidents. I am a Professor of Mathematics at St. Olaf College in Minnesota.

What I first would like to say very strongly on behalf of the Council of Scientific Society Presidents is that we give our unqualified endorsement to the legislation, H.R. 996, that you have submitted. We believe that that is a balanced and equitable and highly visible bill that will send a good signal to encourage students to study science and engineering and mathematics.

I would like to stress particularly, as many of the previous speakers have, the importance for the United States that we draw our scientific leadership from all parts of our population, and that is one of the attractive features, I believe, in H.R. 996, is that by providing awards in each Congressional district, one to a man and one to a woman, it will spread the visibility of science in an equitable manner across the entire nation.

The Council also particularly appreciates the fact that this bill as well all of them that are under consideration now before this committee are centered in the National Science Foundation. Several of the other speakers earlier testified eloquently to the benefit that comes when you have active research scientists engaged in dealing with issues in the schools, and the National Science Foundation is the proper and appropriate governmental agency to carry that out.

I think it would be entirely appropriate for the NSF to work with other organizations to help spread the basis for it, and indeed the members of the Council of Scientific Society Presidents, which consist of 50 scientific societies whose membership base exceeds one million, are already prepared to assist in doing some of the promotional activities that Dr. Atkinson just mentioned.

I would like just briefly to mention a few issues of particulars that differ among the three bills that are being considered. I have submitted written testimony that goes into this in more detail, but there are quite a range of ideas on the agenda of the committee in terms of the bills that were provided to me.

One particular issue is the leverage. The national visibility that comes from a Congressional science award is almost certain to draw additional money and recognition out of the private sector, from colleges themselves, from private donors that provide scholarships for colleges, and I think the legislation would be enhanced if everything possible could be done to provide for that leverage.

Publicity is one way to do it. It might even be possible that it would be appropriate to have more awards, perhaps of a lower value if necessary, in the hopes that you would get more students funded with a mixture of government and private funding.

The important thing that the legislation provides is national recognition and visibility.

The second issue concerns the technicalities of the way colleges and universities administer student aid. Virtually all schools manage their financial aid programs on the basis of need. So a student who receives a scholarship will in many cases, if they also have financial need, will discover that the award that they receive from the college will be reduced by the amount of their scholarship.

I think it would be very helpful if the legislation could be written in such a way that would guarantee that the students who receive these awards actually benefit directly from them.

My third point of concern that I want you to look at carefully as you consider the three different bills has to do with the service requirements that were in—not in Congressman Walgren's bill, but in the other ones.

Science is a very serendipitous activity, and as students go through their undergraduate years especially, and frequently in the junior and senior year, when they suddenly wake up to their potential to issues and interests, it is very common, and I think very healthy, that they have a chance to shape their own professional future with a certain amount of flexibility, and I would hate to see a program that was too restrictive in one particular direction or another. I think that both science and education would thrive on maintaining flexibility.

So in summary, I would like to just reiterate that the Council of Scientific Society Presidents provides its unequivocal support to H.R. 996. We believe it represents a sound and equitable approach to a pressing national need.

And thank you very much for the opportunity to appear.

[The complete prepared statement of Professor Steen follows:]

COUNCIL OF SCIENTIFIC SOCIETY PRESIDENTS

Statement of the Council of Scientific Society Presidents

on

Proposed Congressional Scholarship Initiatives

before the

Subcommittee on Science, Research and Technology

House Committee on Science, Space and Technology

by

Lynn Arthur Steen

Chairman

Council of Scientific Society Presidents

Proposed Congressional Scholarship Initiatives

Statement before the
Subcommittee on Science, Research, and Technology
House Committee on Science, Space, and Technology
2318 Rayburn House Office Building
Thursday, March 9, 1989

Mr. Chairman, Members of the Committee. My name is Lynn Arthur Steen. I am Chairman of the Council of Scientific Society Presidents (CSSP), former President of the Mathematical Association of America, and Professor of Mathematics at St. Olaf College in Northfield, Minnesota.

The Council of Scientific Society Presidents is made up of the presidents and other senior officers of 48 scientific organizations with a cumulative membership of well over 1 million. The Council membership spans the full spectrum of the physical, mathematical, and life sciences.

It is an honor and a pleasure for me to appear before you today in support of the new initiatives proposing scholarship programs in science, mathematics, and engineering. These initiatives are timely, appropriate, and necessary to ensure continued strength of scientific research in the United States.

Science Education

I hardly need to remind you of the ample recent evidence of weakness in mathematics and science education in the United States. In international comparisons of school science and mathematics, our average scores are always well below international norms. Moreover, declining interest among U.S. students in mathematics and science threatens a serious shortage of scientific and engineering professionals before the beginning of the next century.

Weakness in mathematics and science education is especially disturbing for members of minority groups in our society, since their economic future is jeopardized by their extraordinarily high drop-out rates from school mathematics and science courses. The United States cannot sustain strength in science with leadership drawn only from one third of our people—white males. We need to attract the most talented students from all parts of society to careers in mathematics, science, and engineering.

Chairman Walgren forcefully summarized these concerns in his Congressional Record statement of February 9, 1989. I could cite many additional examples that have come to my attention through my service on the Advisory Committee for the

Mathematical Sciences of the National Science Foundation, and on the Mathematical Sciences Education Board at the National Research Council. (For your information, I have attached one of my recent articles, "Out from Underachievement," which appeared recently in *Issues in Science and Technology*.)

Science Scholarships

Several bills have been proposed to establish scholarships for college students intending to pursue careers in science, mathematics, and engineering. The Council of Scientific Society Presidents enthusiastically supports the objectives of these bills. At its meeting of December 3, 1986, the Council unanimously adopted the following resolution:

> CSSP recognizes the urgent need to attract talented youth to careers in science, mathematics, and engineering. Congress should take steps to enable colleges and universities to offer high-quality scientific instruction to their most able students, and should encourage programs through which outstanding undergraduate students in science, mathematics, and engineering can receive scholarships to support their studies.

The full text of this statement is appended, as are related CSSP statements calling for new or improved initiatives in science and mathematics education. As you will see from these statements, CSSP has consistently supported efforts to strengthen the role of mathematics and science education at the National Science Foundation, especially to ensure appropriate and sufficient programs at all educational levels.

More specifically, I am here today to express the Council's unqualified endorsement of the CASE legislation H.R. 996, the "Congressional Scholarships for Science, Mathematics, and Engineering Act." This bill seeks to improve science, mathematics, and engineering education through a Congressional scholarship program that is balanced, equitable, and highly visible. It will send a good signal to the youth of our nation.

H.R. 996 gives equal opportunity to men and women striving for excellence in scientific fields that are critically important for our nation's future. By providing two scholarships each year—one for a man, one for a woman—in every Congressional district, it assures both equitable access and uniform visibility for these awards.

All three bills under discussion today—those of Congressmen Boehlert, Slaughter, and Walgren—build on the established record of achievement of the National Science Foundation. They are founded on the strength and integrity of a merit-based review and selection process. They would strengthen the vertical integration of learning from school science through research by ensuring active participation of scientists and engineers in the identification, selection, and encouragement of scholarship candidates. They help complete a broad portfolio of programs that will enable the National Science Foundation to fulfill its mission.

I am delighted, on behalf of the Council of Scientific Society Presidents, to commend you on this legislation, which reflects many of the priorities expressed by CSSP in recent years.

Important Issues

Whereas Congressman Walgren's bill proposes scholarship awards to high school seniors, the two proposed bills by Congressmen Boehlert and Slaughter would establish awards for college juniors and seniors who intend to enter certain careers in science. One bill stresses the need for science teachers, the other is more broad. Both of the undergraduate scholarship bills require appropriate service as a condition of the award. As you consider these different bills, I urge you to examine carefully certain provisions that will have great bearing on the extent to which the programs fulfill their intended objectives:

- **LEVERAGE.** In many ways, the visibility attached to a Congressional Science Award is at least as beneficial as is the monetary award. A Congressional Science Award makes science visible to parents, teachers, school boards, and students. The attendant publicity surrounding the competition will help retain the interest and hard work of able students. Colleges and universities will compete with each other to recruit students who receive these awards, as well as those who merit honorable mention. Scholarship funds provided by colleges and universities to those identified during the search process may well exceed those provided by Congress; indeed, it is quite likely that alumni and private donors will be eager to provide scholarship support to colleges and universities to enable them to make competitive offers to these award-winning students.

  To ensure the widest possible impact of the program, it might, therefore, be preferable to provide more awards of a smaller nature. Compare, for instance, the effect on our national need for scientists of having ten awards in each Congressional District, even if it meant that the annual monetary award were only $1000. In such a case, every high school in the nation could realistically aspire to having a senior receive this award, at least once every few years.

- **NEED.** Since most colleges base financial aid awards on need, many students who receive a science scholarship will find their financial aid award reduced dollar for dollar by the amount of their scholarship. Only those from families that are sufficiently wealthy to not qualify for aid may receive full financial benefit from the scholarship. It would be good if the legislation could be written in a way to ensure that all students who received an award will benefit equally. This could be done, for instance, by requiring that only the self-help part of the financial aid package (loans and campus work assignments) be reduced for a student who holds a Congressional Science Award.

- **LOANS.** Scholarships linked to future jobs—such as teaching school science or mathematics, or service "in the employ of the United States"—necessarily require stringent conditions about repayment in case the recipient fails to complete the service obligation. The tone and language of such conditions conveys the impression of default or irresponsibility, which may not be warranted in the legitimate (and common) case of a prospective school teacher who may decide, for instance, to pursue graduate study for a career in medical research. It is an important function of education to expand students' horizons and open opportunities for use of each student's talents in ways that cannot easily be foreseen. Moreover, science thrives in response to the unexpected—witness superconductivity, AIDS, and ozone depletion—so effective programs must provide maximum flexibility for talented young scientists to pursue science itself, unencumbered by prior commitments made while in high school or college.

If awards must be tied to future jobs, it probably would be better to structure them as forgivable loans—much as was done with the National Defense Education Act (NDEA) loans three decades ago. In such a program the individual can freely choose, without prejudice, either to take a position under the terms of the loan, or to take a different job. In the former case, the loan would be forgiven; in the latter, the awardee would be responsible for repaying the loan. Such a mechanism would provide flexibility for Congress to establish incentives for areas of national need—for example, nursing, science teaching, or rural doctors. A loan program of this type could support more students on the same budget (because some portion of the loans would be repaid) and also provide flexibility for regular Congressional review to ensure that subsidized careers continue to reflect national priorities.

- TEACHING. The bill introduced by Congressman Boehlert is narrower in scope than the other two in that it focuses on the special need to recruit science and mathematics teachers. The nation needs both science majors and science teachers. It also needs a scientifically literate population. Insofar as all three bills call attention to the importance of science and engineering for our nation's future, they serve an important purpose. Insofar as they provide financial awards as inducements for students, priority should be given to the areas where both financial and national need is greatest. Science teaching is surely one of these areas.

- TIMING. H.R. 996 proposes scholarships to be awarded to high school students *after* they have been admitted to an accredited institution of higher education. That restriction on timing—which places the awards late in the student's senior year—may not provide the best leverage to encourage talented students to enter careers in science. Much of the agonizing about potential career choice takes place in the fall when students first think about applying to college. Wouldn't it provide more encouragement to attract those who are not already committed to science by letting students know at the beginning of their senior year in high school that they will have a Congressional Science Award if they decide to choose a science program in college?

Grass Roots Support

A favorable attribute of H.R. 996—and of any science scholarship program whose administration is structured at the local level—is that it promises significant leverage for a modest annual investment of federal funds. When CSSP voted to endorse this legislation, the Council expressed its commitment "to assist with support activities such as . . . encouraging our societies and society members to support the program at the local level."

Programs such as H.R. 996 provide a vehicle for the scientific community—individuals and organizations alike—to become involved in local (as well as national) discussions about science education. Many professional scientific societies are developing plans to actively support a science scholarship program if it is enacted, and to introduce the awardees to the disciplinary profession(s) of their choice. CSSP has recently received outlines of these kinds of efforts from several of our member societies. Copies of some of these plans are provided for the Committee as attachments to this statement.

A process of selection and award of scholarships determined by Congressional districts will have the beneficial effect of introducing members of Congress and their staffs to scientists in their districts—to members of the scientific professional societies who are, in many cases, more active locally than nationally. These contacts should lead to better understanding of issues pertaining not only to science education, but also to environment, health, and scientific research. Second order effects such as these are important benefits of this type of legislation.

Conclusion

In summary, Mr. Chairman, the Council of Scientific Society Presidents finds that a national program of awards for undergraduate mathematics, science, and engineering students is timely and important for our nation. It is appropriate that such awards by administered by the National Science Foundation, both to ensure merit-based scientific review as well as to enable NSF to fulfill its mission in science education. The CASE scholarships proposed in H.R. 996, in particular, represent a sound and equitable approach to this national need.

Nationally visible science scholarships represent a worthwhile investment of resources toward solving one of our nation's most pressing long-term problems: declining interest and competence among our youth in science, mathematics, and engineering. Unless reversed by special programs such as H.R. 996, continued widespread ignorance of science and its societal implications will constitute a serious threat to the health and welfare of our Nation.

Thank you for the opportunity to present these remarks; I would be pleased to respond to any comments or questions that you might have.

1989 Council of Scientific Society Presidents

Dr. Carl A. Burtis
American Association for Clinical Chemistry

Dr. James E. Tingstad
American Association of Pharmaceutical Scientists

Dr. Faiz M. Khan
American Association of Physicists in Medicine

Dr. Gerald Wheeler
American Association of Physics Teachers

Dr. Clayton F. Callis
American Chemical Society

Dr. Bryan Craven
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Dr. Howard L. Funk
American Federation of Information Processing Societies, Inc.

Dr. Don L. Anderson
American Geophysical Union

John Patrick Jordan
American Institute of Biological Sciences

Dr. James N. BeMiller
American Institute of Chemists, Inc.

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American Mathematical Association of Two-Year Colleges

Prof. William Browder
American Mathematical Society

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Dr. Joseph Matarazzo
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Dr. Janet Spence
American Psychological Society

Dr. Robert T. Schimke
American Society for Biochemistry and
Molecular Biology

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American Society for Cell Biology

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American Association for Mass Spectrometry
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American Society of Zoologists
Harvard University

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Botanical Society of America

Dr. Lynn Arthur Steen
Conference Board of the Mathmatical
Sciences

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Council for Chemical Research

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Dr. Harold A. Mooney
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and Cognitive Science

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Health Physics Society

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Institute of Food Technologists

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The Institute of Management Sciences

Dr. Lida K. Barrett
Mathematical Association of America

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National Association of Biology Teachers

Dr. Shirley Frye
National Council of Teachers of Mathematics

LaMoine Motz
National Science Teachers Association

Prof. Donald Gross
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Soil Science Society of America

LYNN ARTHUR STEEN

Out from Underachievement

To sustain scientific innovation in the 1990s and beyond, we need to revitalize school mathematics today.

On the national political stump, education has joined motherhood and apple pie. In numbing unison, Republicans echo Democrats and conservatives support liberals in arguing that education must be a top national priority.

Much of the concern with education centers on our diminishing international competitiveness. The evidence is indisputable that in a world of multinational corporations and international markets, inventiveness in science and technology—rather than abundance of labor or natural resources—is the major asset available to U.S. industries. But equally indisputable is evidence that U.S. leadership in science and technology is rapidly diminishing; as a nation, we are simply not renewing our intellectual capital.

Because of the widespread utility of mathematics in scientific and technological applications, mathematics education is a key predictor of scientific competitiveness. Yet, recent international studies—such as the aptly titled *The Underachieving Curriculum,* based on the Second International Assessment of Mathematics Education—show that the mathematics yield of U.S. schools is substantially less than that of other industrialized countries and far below the levels necessary to sustain our nation's present position of leadership in scientific inventiveness.

To make matters worse, the immense impact of computers on science and mathematics compels major reexamination of objectives and standards for school mathematics. Not only has computing changed the way mathematics is used, thus altering the balance between essential and peripheral topics, but computing has mathematicized science and technology. No longer is it sufficient for theoretical scientists alone to have a working knowledge of mathematics; now all scientists—indeed, virtually all professionals—encounter mathematical models in much of what they do. Contrary to common belief, the ubiquity of computers in the workplace means that today's students need more rather than less mathematics.

Calls for change

The Carnegie Foundation recently launched a major initiative to overhaul the teaching profession. It calls

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Lynn A. Steen is Professor of Mathematics at St. Olaf College in Northfield, Minnesota. He is chairman of the Conference Board of the Mathematical Sciences and past president of the Mathematical Association of America.

for radical changes in the way teachers are educated and in the way schools are operated, all designed to ensure that teachers grow as professionals with increasing respect, autonomy, and responsibility (and commensurate compensation). Such changes, according to Carnegie, will enable teachers to improve the quality of education.

In a similar spirit, three national reports in mathematics and science education are due to appear this year or next, sponsored by the National Council of Teachers of Mathematics (NCTM), the Mathematical Sciences Education Board (MSEB) of the National Research Council, and the American Association for the Advancement of Science (AAAS). Although these undertakings differ greatly in detail and purpose, they generally agree that schools must increase student involvement in learning by fostering a broad view of mathematics, by increasing use of computers, by linking mathematics to science, and by stimulating student-led projects.

Meanwhile, governors, state legislatures, and school boards are resolving to improve what happens in schools by increasing emphasis on accountability. By basing the allocation of resources on actual performance, political leaders expect free-market forces to ensure survival of the fittest in educational programs. They argue that greater competition, and the application of higher standards, will enable administrators and teachers to assess results and act accordingly to improve the quality of their schools.

Not surprisingly, educators, politicians, and scientists do not speak with one voice. For example, increased emphasis on assessment usually leads to less autonomy for teachers and more emphasis on skills, while greater stress on student involvement in learning tends to make assessment more difficult.

Nonetheless, the basis of a national consensus is forming. Now, not only can political candidates tell us that they believe in education, they can actually do something about it: They can stress five areas—expectations, testing, learning, teaching, and education—as planks for a national platform to support our children (and our country) as we prepare to enter the twenty-first century.

Expectations

Independence is the hallmark of U.S. educational policy, which is set not by the U.S. Department of Education but by 16,000 local school districts. Local control of education is deeply embedded in the American body politic, a legacy of constitutional authority that reserves to the states all matters not expressly granted to the federal government.

Yet this independence is largely a myth, especially for mathematics education. Effective control comes not from Washington bureaucrats, but from invisible state committees that approve textbooks and anonymous officials who administer standardized tests. Few facts stand undisputed in educational research, but the dependence of teachers on textbooks and of students on tests is as deep an insight as exists in this amorphous discipline: teachers teach only what is in the textbook, and students learn only what will be on the test.

The result for mathematics education is a de facto national curriculum. It is an "underachieving" curriculum that follows a spiral of constant radius, each year reviewing so much of the past that little new learning takes place.

Some states (such as California, Texas, Wisconsin, and New York) have recently promulgated new standards for mathematics education, often with surprising consequences. In California, new standards led to initial rejection of all mathematics textbook series submitted for authorized adoption—principally because the texts failed to adequately develop student capabilities to address and solve complex, subtle, and unpredictable problems.

To focus attention on the *national* need for improved standards in school mathematics, the National Council of Teachers of Mathematics is preparing a detailed report spelling out important new goals both in content (by grade level) and in instructional practice. These standards speak about what is necessary and what is possible in today's mathematics classroom: that students should learn not only arithmetic but estimation, measurement, geometry, statistics, and probability—all the ways in which mathematics occurs in everyday life—and that they should gain confidence in their ability to communicate and reason about mathematics.

These new standards specify, for example, that all children in primary school should learn to use estimation techniques whenever appropriate, to use calculators as tools for computation, and to explore alternative strategies for solving problems. Statistical ideas permeate the standards from primary grades ("use data to make predictions; experiment with concepts of chance") to high school ("design a statistical experiment and communicate the outcomes"), because statistics permeates the society in which we live.

We must judge schools not by remembrances of things past but by necessary expectations for the future. Members of school boards, accrediting agencies, and state legislatures must first educate themselves about these new standards, and then insist that they actually be used by school districts to evaluate the mathematics education they provide.

> *In a sense, no one can teach mathematics. What we hope is that a good teacher can stimulate a student to learn mathematics.*

Testing

Governors all over the country are talking about "assessment" in order to raise expectations and evaluate programs. And with good reason; assessment is an integral part of teaching. It is the mechanism whereby teachers can learn how students think and what they are able to accomplish. Assessment is also used to evaluate student performance, to compare classes and schools, and to place students in future courses or careers. Because assessment is so pervasive and has such powerful impact on the lives of both students and teachers, it is very important that assessment practice align properly with curricular objectives.

Unfortunately, assessment in mathematics education is rarely used properly. Tests designed for diagnostic purposes are used for evaluation of programs; scores from self-selected populations (e.g., takers of the Scholastic Aptitude Test) are used to compare districts and states; and commonly used achievement tests stress simple skills rather than sophisticated tasks, not because such skills are more important but because they are easier to measure.

As we need standards for curriculum, so we need standards for assessment. Both those who ask for assessment and those who use the results of assessment must ensure that we test what is of value, not just what is easy. In the past, assessments have emphasized computational and mimicry aspects of the curriculum, at the expense of such "holistic" expectations as the student's ability to formulate problems, invent strategies, develop lines of argument, and communicate reasons. That's like judging student writing solely on the basis of spelling and grammar, without paying any attention to what the student is trying to say. Rather than merely validate computation with multiple-choice, right-or-wrong questions, we must seek ways to assess such mathematical traits as flexibility, imagination, persistence, and skepticism.

Some will argue that tests cannot change rapidly lest new data be incompatible with past records. That is an argument for preserving the status quo, no matter how outdated it is. By confusing means and ends, by making testing more important than learning, it holds today's students hostage to yesterday's mistakes.

As new standards emerge for school mathematics, assessment must change to match the entire breadth of curricular objectives. If tests do not change, nothing will change. Conversely, there is no more rapid way to improve mathematics education than to change the standards for assessment. Agencies charged with ensuring quality education—governors, legislatures, state departments of education, and accrediting agencies—have the power to make or break present efforts to improve mathematics education by the way they control assessment practice. States and schools must match assessment practice to new standards of instruction.

Learning

Despite mountains of daily homework, mathematics is primarily a passive activity for most students: teachers prescribe, students transcribe. Most teachers present mathematics as established doctrine, employing a "broadcast" metaphor for learning that stresses right answers rather than clear, creative thinking. In the early grades, arithmetic becomes the stalking-horse for this authoritarian model of learning, sowing seeds of expectation that dominate student attitudes all the way through college. What mathematics teacher isn't plagued with the query "Can't you just tell me the answer?"

Yet educational research provides unequivocal evidence that students learn mathematics well only when they explore it on their own, constructing strategies that bear little resemblance to the canonical examples presented in standard textbooks. Just as children need the opportunity to learn from mistakes, so students need an environment for learning mathematics that provides generous room for trial and error.

Classes in which students are told how to solve a quadratic equation and then assigned a dozen homework problems to learn the approved method will rarely stimulate much lasting mathematical knowledge. A far better strategy is to let students encounter such equations in a natural context: explore approaches to solutions including estimation, graphing, computers, and algebra; and then compare various approaches and argue about their merits. To learn mathematics, students must act out the verbs—"examine," "represent," "transform," "solve," "apply," "prove," and "communicate"—in the new curriculum standards.

In the long run, it is not mathematical skills themselves that are particularly important—for without constant use, skills rapidly fade—but the confidence that one knows how to find and use mathematical tools whenever they become necessary. Only through the process of creating, constructing, and discovering mathematics can this confidence be built.

To encourage students to create, discover, and construct as they learn, states must establish guidelines for the environment in which learning takes place. Administrators and school boards must provide teacher aides, appropriate equipment, and reasonable class sizes so that active learning is possible. And then they must insist that learning actually *be* active.

Teaching

In a sense, no one can teach mathematics. What we hope is that a good teacher can stimulate a student to *learn* mathematics.

For this to occur, teachers need to know how to explore, to guess, to test, to estimate, and to prove. They need confidence that they can respond constructively to unexpected conjectures that emerge as students also explore, guess, test, estimate, and prove. Too often, mathematics teachers are afraid that someone will ask a question that they can't answer. Insecurity breeds rigidity, the antithesis of mathematical power.

At every level, but especially in their college and university courses, prospective teachers should learn their mathematics in a manner consistent with the style in which they will be expected to teach—as a process of constructing and interpreting patterns, of devising strategies for solving problems, and of discovering the beauty and applications of mathematics. Above all, courses taken by prospective teachers must create in these teachers confidence in their own abilities to help students learn to appreciate the richness and excitement in mathematics.

So here is a task for colleges and universities: teach teachers as we would have them teach. It will not be easy to find sufficient faculty well equipped for this task, for college mathematics is, on the whole, presented in the same authoritarian manner as school mathematics. After all, teachers teach as they were taught. Perhaps the National Science Foundation should stress quality teaching in science and mathematics even as it stresses quality research, as much to redefine the academic reward system as to stimulate innovation in undergraduate instruction.

Teacher education

Two recent reports by the Carnegie Commission and the Holmes Group of major universities recommend abolishing the undergraduate major in education as a necessary first step for reinjecting quality in public schools. These recommendations are based on two laudable objectives: to ensure that teachers are well grounded in the subjects they teach, and that able students are attracted to careers in teaching.

Those who would teach mathematics need to learn contemporary mathematics appropriate to the grades they will teach, in a style consistent with the way in which they will be expected to teach. They also need to learn how students learn—what we know from research (not much, but important), and what we do not know (a great deal). And they need to learn enough about science, technology, business, and social science so that they can convey mathematics in the contexts where it most naturally arises—in measurement, graphing, prediction, and data analysis.

Because mathematics is one of the few disciplines taught throughout the entire 13 years of school (K-12) and sequential growth is a firm prerequisite for moving from one level to the next, the education of elementary school teachers is especially important. Yet the United States is one of few countries in the world that continues to pretend, despite massive evidence to the contrary, that elementary school teachers are able to teach all subjects equally well. The reality is that elementary teachers too often take just one course in mathematics, approaching it with trepidation and leaving it with relief. Such teachers are unlikely to inspire children to have confidence in their own abilities to construct mathematics appropriate to their lives. Often, experienced elementary teachers move up to middle grades (because of imbalance in enrollments) without ever learning any more mathematics. It is profiles such as these—not universal, but not at all uncommon—that compel thoughtful people to say that enough is enough.

We must modify expectations, testing, learning, teaching, and teacher education all at the same time.

It is time that we educated a cadre of elementary mathematics specialists well prepared to teach young children both mathematics and science in an integrated, discovery-based environment. To bring this about, states must alter certification requirements to encourage effective use of such teachers. For example, math/science teachers can be paired with language arts teachers in the primary grades; alternatively, a math/science specialist could lead faculty development in an entire school. Meanwhile, universities must implement new mathematics courses with instructors who will inspire prospective school teachers to grow with confidence.

Strategies for change

It is not enough to say that education is our number one priority, or that we must emphasize science and mathematics to improve our international competitiveness. We need concrete policies and programs for implementing a broad new mathematics agenda. We must avoid piecemeal approaches and their inevitably modest effects: When most of the complex educational system remains fixed while only parts of it change, little improvement will result. We must therefore modify expectations, testing, learning, teaching, and teacher education all at the same time.

That may sound like a prescription for a revolution. But it can be achieved, far more effectively, by punctuated evolution. Because mathematics education involves millions of people, the system cannot change quickly. Instead, strategies for change must be orchestrated so that everyone moves in the same direction, at the same time. Above all, we must avoid the temptation of quick fixes or simplistic solutions.

Coordinating a nationwide plan to improve mathematics education is a serious challenge to political leaders. Scientists and mathematicians, for example, can set standards for their disciplines and illuminate productive pathways for educational progress, but they rarely know how to operate in the educational arena. Educators generally know how to change various pieces of the puzzle, but they rarely have either the perspective or the power to effect large-scale change.

Leadership to improve mathematics education must therefore move beyond academe to the broader arena of public policy, provided such leadership is informed by sound understanding of the issues. The agenda should include the following:

- Promote high expectations of school mathematics based on new standards rather than old "basics."
- Disavow simplistic proposals and mindless comparisons of test scores.
- Require that official assessment instruments match current curricular objectives.
- Fund summer programs for talented youth to nurture a new generation of teachers and scientists.
- Encourage widespread use of calculators and computers as tools for calculation and instruments of discovery.
- Create incentives for universities to support quality undergraduate teaching as strongly as quality research.
- Require that all new teachers meet current standards for professional preparation.

- Provide ample opportunities for continuing mathematical education for all who teach school mathematics.

Details of this agenda will appear in reports to be issued during the next several months by both the Mathematical Sciences Education Board and the National Council of Teachers of Mathematics. Every governor, every legislator, and especially our next president should use these reports to help frame an effective policy for revitalizing mathematics education. Our goal for the 1990s must be to make mathematics a pump rather than a filter in our nation's educational pipeline.

Recommended reading

American Association for the Advancement of Science. *What Science is Most Worth Knowing?* Draft Report of Phase I, Project 2061, December 1987.

The Carnegie Forum on Education and the Economy. *A Nation Prepared: Teachers for the 21st Century.* Report of the Task Force on Teaching as a Profession, 1986.

Thomas Cooney, "The Issue of Reform: What Have We Learned from Yesteryear?" *Mathematics Teacher* 81 (May 1988): 352–363.

Mathematical Association of America. *Recommendations on the Mathematical Preparation of Teachers.* 1985.

Curtis C. McKnight et al. (eds.), *The Underachieving Curriculum: Assessing U.S. School Mathematics from an International Perspective.* Champaign, Ill.: Stipes Publishing, 1987.

National Council of Teachers of Mathematics, *An Agenda for Action: Recommendations for School Mathematics of the 1980s.* 1980.

National Council of Teachers of Mathematics, *Curriculum and Evaluation Standard for School Mathematics.* Working Draft, October 1987.

National Research Council, *A Framework for Revision of the K-12 Mathematics Curriculum.* Task Force Report to the Mathematical Sciences Education Board, 1988.

Lauren B. Resnick, *Education and Learning to Think.* Washington, D.C.: National Academy Press, 1987.

Lynn Arthur Steen (ed.), *Calculus for a New Century: A Pump, Not a Filter.* Mathematical Association of America, 1988.

Lynn Arthur Steen, "Mathematics Education: A Predictor of Scientific Competitiveness," *Science* 237 (July 17, 1987): 251–252, 302.

Harold W. Stevenson et al., "Mathematics Achievement of Chinese, Japanese, and American Children," *Science* 231 (Feb. 14, 1986): 693–699.

COUNCIL OF SCIENTIFIC SOCIETY PRESIDENTS

Resolution adopted by the
Council of Scientific Society Presidents

December 3, 1986

SCHOLARSHIPS TO OUTSTANDING UNDERGRADUATE STUDENTS IN SCIENCE, MATHEMATICS, AND ENGINEERING

The Council of Scientific Society Presidents recognizes the urgent need to attract talented youth to careers in science, mathematics, and engineering. We urge therefore that Congress take steps to enable colleges and universities to offer high-quality scientific instruction to their most able students, and to encourage programs through which outstanding undergraduate students in science, mathematics, and engineering can receive special scholarships to support their studies.

Our national welfare, technological competitiveness, and national security depend on our scientific and technical competence. The cost of providing technical education for our most able students might be shared by industrial, state, and federal sources.

An example of a program which would strengthen our national capability in science and technology is found in the report entitled "A Renewed Partnership" prepared by the White House Science Council Panel on the Health of U.S. Colleges and Universities, cochaired by Dr. David Packard and Professor D. Allan Bromley:

> "A substantial program of merit-based, portable scholarships should be established by the federal government at the undergraduate level. Parallel programs should be established by all industries having significant dependence upon university research and education. The national goal should be for the most able 1 percent of the undergraduate students in mathematics, engineering, and the natural sciences entering colleges or universities each year to be supported under these programs. This program is recommended as an addition to, not a substitution for, existing need-based federal assistance programs." (Section V. The Environment for Academic Research and Education, Subsection 9, Recommendation 5, page 29 & 30)

COUNCIL OF SCIENTIFIC SOCIETY PRESIDENTS

Council of Scientific Society Presidents Statement on Undergraduate Education

December 4, 1985

The Council of Scientific Society Presidents endorses the initative of the National Science Board in undertaking a study of undergraduate science, mathematics, and engineering education. The undergraduate years are a crucial period in the education of all who are headed for careers in mathematics, science, or technology. As was well-documented by earlier testimony to the Board, signs of weakness abound in science and mathematics programs at the undergraduate level. Because of severely inadequate funding levels for undergraduate education, the National Science Foundation has been unable to provide national leadership and resources to help bring about necessary improvements. Therefore, we strongly urge the National Science Board and the National Science Foundation to restore strong support for collegiate science, mathematics, and engineering education.

COUNCIL OF SCIENTIFIC SOCIETY PRESIDENTS

RESOLUTION ON NATIONAL SCIENCE BOARD'S UNDERGRADUATE REPORT

MAY 14, 1986

The Council of Scientific Society Presidents (CSSP) warmly endorses the efforts of the National Science Board (NSB) to focus attention on the many pressing needs of undergraduate education in science, mathematics, and engineering. We applaud the NSB Task Committee on Undergraduate Science and Engineering Education for the thoroughness and timeliness of the recently released report to the Science Board (NSB 86-100). We are pleased that the Board has accepted the leadership role defined by the Task Committee in the promotion of excellence in undergraduate teaching and learning.

CSSP appreciates that, not only NSF, but also other agencies--colleges, universities, states,private foundations, and federal agencies--must respond with vision to avert serious potential crises in the collegiate infrastructure of science and technology.

CSSP, while very supportive of the Foundation's much needed efforts to improve the quality of science, mathematics, and engineering education in the nation's elementary and secondary schools, has been concerned for sometime that comparable efforts have not been undertaken at the undergraduate level. We appreciate the need of the Foundation, given the economic exigencies under which it must operate, to support only "leveraged" activities. We urge NSF to initiate clearly defined programs of national scope that will help marshall both public and private resources to improve the quality of undergraduate instruction in science, mathematics, and technology.

Thus, CSSP supports the level of funding for undergraduate programs as indicated in NSB 86-100 as the minimum required to accomplish the task at hand. We would caution that these funds not be diverted from precollege educational activities, which still are in critical need of support from the Foundation. We trust that each research division of NSF will actively cooperate with the Directorate for Science and Engineering Education in developing undergraduate programs appropriate to the various disciplines.

This country cannot maintain its leadership position in the field of scientific and engineering research unless the foundations for this research--vital imaginative, comprehensive, and appropriate undergraduate education in science, mathematics, and engineering--are firmly in place for all our students.

COUNCIL OF SCIENTIFIC SOCIETY PRESIDENTS

1987

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February 25, 1987

The Honorable Robert A. Roe
Chairman
Committee on Science, Space,
  & Technology
U.S. House of Representatives
Washington, D.C.   20515

Dear Representative Roe:

The Council of Scientific Society Presidents (CSSP), an organization made up of the presidents of more than 30 scientific societies with a combined membership in excess of 800,000, reviewed the 62 recommendations offered by Mr. Fuqua upon his retirement from Congress, and the CSSP Executive Board has approved for your consideration the following observations. (In the text that follows, the numbers in parentheses refer to the corresponding recommendation.)

In his farewell message to the House Science and Technology Committee, Chairman Don Fuqua called for increased federal support for science "...even in times of deficit reduction (1)." The Executive Board agrees with this call, but would replace "even" with "especially." Strong support for science is essential not only to the quality of life through its applications in technological development but also because it represents a national commitment to the ethos of open inquiry designed to provide deeper insights into the nature of the universe in which we live. Mr. Fuqua's recommendations are comprehensive and constructive. We commend him not only for the thoughtfulness of the recommendations in his farewell address but also for his many substantial contributions to science over his years of service as a Member of Congress.

In supporting his recommendation that basic science receive at least 1% of the federal budget (1), we urge particular attention to his recommendation that a careful distinction be made between basic research and development (25) and that they be budgeted separately with better overall planning, to be sure that no important basic research is being neglected. The linkages between research and development are necessarily close, but, without a distinction for the purposes of resource allocation, support for basic research can be diverted inadvertently to serve short-term needs in the absence of the basic knowledge required for sound development (33). This distinction would be of considerable value in assessing the decline of support for basic research in the military R & D (23).

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The views expressed by CSSP are those of its members and do not necessarily represent the official position of their respective organizations.

The need for a significant increase in support levels for basic research is evident in several ways beyond the decline of such support from military R & D. Research programs recommended for support on the basis of quality far exceed the funds available for them. In addition, even a conservative long-range international policy regarding support of large-scale science (18, 19, 20, 21, 22) will threaten "small" science in the absence of additional base levels of support (21). Mr. Fuqua's commitment to support for individuals, and primarily for young investigators (33) implies additional support, particularly in view of the many excellent research proposals which are rejected strictly for lack of funding. There may be "marginal" researchers for whom support should be reduced (33), but merit review, high levels of competition, and obvious funding shortages assure that support for marginal research is minimal.

Mr. Fuqua's support for science and mathematics education is most welcome to the CSSP. The quality and quantity of future science will be determined directly by today's education.

There is a pressing need for reliable and valid data regarding education (42). Such information must include matters of quality as well as quantity, and must be sufficiently specific to identify, for example, a shortage of qualified mathematics or chemistry teachers even if there happens to be a sufficient supply of certified biology teachers. Continuous collection, analysis and publication of such information is certainly a principal unfulfilled responsibility of the federal government.

Even with the limited data now available, there can be little doubt that the scientific enterprise will be strengthened with more support for excellent students (41), greater scientific literacy among the population at large (42), and universal access to calculators and computers in our schools (47).

We welcome Mr. Fuqua's strong support for improving the quality and quantity of precollege mathematics and science instructors (40), but the steps employed to increase the quantity of instructors must avoid damaging quality. "Unconventional solutions" (40), will certainly be needed, but no simple competency test is likely to enhance or even maintain quality. Nothing short of excellent educational programs and enhanced support for those in the teaching profession will solve what is now recognized as a crisis in science and mathematics education at the primary and secondary levels.

We have serious reservations about the proposal to move responsibility for science and mathematics education from the National Science Foundation to the Department of Education (40). We believe firmly that science education should be linked with science and scientists and that the role of the National Science Foundation in fostering science and mathematics education should be expanded. It is important, too, that pedagogical research be conducted with the direct involvement of individuals from the physical, biological, mathematical, behavioral, and cognitive sciences as well as from the pedagogical disciplines.

We believe the long term quality of scientific research at our nation's universities is in jeopardy if capital facilities are not maintained and enhanced. Mr. Fuqua's proposals (4,5,6) are innovative and constructive, but support for capital facilities cannot be drawn from the existing science support base without serious jeopardy to the overall scientific enterprise and, in particular, to the young investigators whose development is essential to the definition of the science of the 21st century. We support Mr. Fuqua's call for long range planning and annual budgeting for infrastructure but note that this cannot be done solely by the universities. National mechanisms for maintaining support facilities are needed.

We can agree that "total freedom" in science and technology is unrealistic (15)--indeed we doubt that any serious scientist even suggests that it is either wise or possible in the contemporary world--and recognize that both ethical responsibility and social concerns play a role in virtually all research. To address these issues appropriately requires the involvement of broad segments of the intellectual community as part of the continuing congressional inquiry suggested by Mr. Fuqua. The National Academy of Sciences, in particular, could play an important role here.

For purposes of developing national policy on support for science, it would be particularly useful for any inquiry to focus, in part, on the extent to which national technological needs not only determine which areas of science should gain support advantages but which areas of science would suffer as a consequence because they are not perceived as immediately necessary for economic, technological, or security interests. This issue is of special importance in any proposed working relationship between NSF and DOD (23). With Mr. Fuqua (24), we strongly urge disavowing the Mansfield Amendment.

Mr. Fuqua's recommendations for models of basic science support (5, 6, 7) merit careful consideration. We heartily support his proposal (5) that institutions receive a fixed percentage of all direct research costs for purposes of long-term infrastructure support. It may also be worth considering establishing a policy of indirect costs being paid as a fixed percentage of direct costs, that percentage being the same for all academic institutions. Present policies result in differing allocations for the same research independent of quality, and can lead to disadvantages for some scientists.

While there may be some justification to providing formula grant support for science in a way which parallels that for agriculture (6), in general this is a model which can work for shorter-term, mission oriented, or developmental research but is not likely to work well for basic science. Theory- and idea-driven science does not lend itself to direct cost formulas.

There may be, as Mr. Fuqua suggests (7), need for additional research universities. However, it is not evident that the targeted approach described will work. Research universities have emerged gradually through the years, and very strong areas of emphasis exist at some universities not now designated "research" universities. This was made possible through local dedication in bringing first-class talent to campuses and this, in turn, produced the federal support needed for additional areas of excellence. Targeting institutions where the tradition of, and investment in, excellence does not exist is likely to be counterproductive.

Mr. Fuqua is to be commended for opposing restrictive legislation in biotechnology and for encouraging the emergence of a strong and competitive biotechnology industry (34). CSSP believes that we do not need new legislation along these lines. We favor the OSTP proposal and existing protective statutes. We strongly oppose restrictive legislation which will impede development of well defined products, such as vitamin C and human insulin. We also oppose unnecessary controls on university research. We must not place so many restraints on this promising new technology that we drive it offshore.

Science is important to the economic well-being, security, and technology of the nation. However, at base it is an intellectual enterprise aspiring to provide an understanding of our universe. This aspiration can be met only through quality merit review of ideas whether they appear in grant proposals or the scientific literature. The astonishing developments of the 20th century are a result of this process at both informal and formal levels. Without a set of guiding heuristics to differentiate the quality of competing ideas, such advances could not have occurred. To be sure, this means that on occasion an ultimately excellent idea or development will be set aside for the short term, but not to have these guiding heuristics, or orthodoxies, would prevent any substantive differentiation. However slowly it may occur, the self-correcting nature of inquiry belies any beliefs either that cronyism (51) or scientific orthodoxy per se (52) play any more than a small, and self-limiting, role in our attempts to support the imaginative work necessary for a healthy science. Similarly, a science will not remain healthy if geographic variables (54) or perceived technological priorities (45) rather that creative ideas play a large role in defining scientific directions.

We endorse Mr. Fuqua's recommendation of a careful review of science policy with emphasis on technology policy (61) and suggest that the National Academy of Sciences and the National Academy of Engineering be employed as part of his proposed continuing assessment pursuant to the Science Policy Task Force's final report (62).

I and my colleagues on the Council would be most pleased to respond to any questions or comments that you or your staff might have on the above observations.

Sincerely,

L. Manning Muntzing

L. Manning Muntzing
Chairman

Attachment

cc: CSSP Executive Board

COUNCIL OF SCIENTIFIC SOCIETY PRESIDENTS

Resolution of the
Executive Board of the
Council of Scientific Society Presidents
Regarding the Administration of Mathematics and Science Education

January 14, 1987

The Executive Board of the Council of Scientific Society Presidents notes with regret the retirement from Congress of Don Fuqua. During his 24 years in Congress and eight years as Chairman of the Committee on Science and Technology he has made many substantial contributions to the health of science in the United States. The entire nation has reason to be grateful.

The forthcoming report of the congressional task force on science policy that Mr. Fuqua headed will undoubtedly be another positive contribution to science in this country. If the Chairman's farewell message to the House Science and Technology Committee is any indication, the report will be thoughtful, provocative, and extremely useful in the essential planning of the country's future support for science, "the keystone of our nation's progress and the backbone of our military security." After the final document is available the full Council will comment on specific issues that the report addresses.

In the meantime, however, many of our members take exception to the last two sentences of Mr. Fuqua's Recommendation No. 40.

> "...The Committee on Science and Technology should hold hearings to determine whether the pre-college education responsibilities of NSF (the National Science Foundation) should not be transferred to the Department of Education, bearing in mind the abysmal record of the NSF in this area. It may well be that the problem of pre-college science education in the nation is better handled by educators than by research scientists."

Given the magnitude of the problem and the federal resources expended to solve it, the NSF record is not abysmal in mathematics and science education. As we have said before, we would like to see a greater commitment on the part of the Federal Government and the leadership of NSF, but transferring mathematics and science education from NSF to the Department of Education is not likely to have a positive effect. We believe the distinction between "educators" and "research scientists" is a false dichotomy. The people who administer federal funds to improve mathematics and science education should be competent in both the content and the profession, and should be committed to both.

Recently we received a report that there are few if any persons with a background in mathematics education, science education, mathematics, or science who are associated with administering Department of Educations funds for improving mathematics and science education.

Given the present positions and personnel of the two agencies, we believe mathematics and science education will be better served at NSF than at the Department of Education, but we encourage both Congress and the leadership of NSF to put still greater effort into alleviating the shortage of competent instructors of mathematics and science at the pre-college levels.

COUNCIL OF SCIENTIFIC SOCIETY PRESIDENTS

Resolutions Adopted by the
Council of Scientific Society Presidents
in Support of
Mathematics and Science Education

May 13, 1987

RESOLUTION A

The Council of Scientific Society Presidents supports increased Federal appropriations to expand summer programs for secondary and elementary mathematics and science teachers.

The objective is to serve a diverse population of teachers, who would become more effective by acquiring further knowledge of content and pedagogy.

Comments

Mathematics and science are becoming more important in understanding and solving the world's problems and in maintaining and improving the competitive position of the United States. Mathematics and science are changing and expanding rapidly. Standard pre-certification teacher preparation programs cannot possibly include all the content and pedagogy needed by teachers today. Teachers who were prepared 10, 20, 30 or even 40 years ago are likely to be inadequately prepared to teach mathematics and science today.

Evidence exists that the NSF institutes of the 1950's and 60's had substantial positive influence on mathematics and science education. Most Presidential Award winners who were teaching at the time institutes were widely available attended one or more, and give very positive evaluations of them.

We believe that programs modified in light of changing circumstances a what we have learned from past institutes provide an economical and effective means of helping mathematics and science teachers attempt to stay abreast of recent developments.

RESOLUTION B

The Federal Government should conduct an annual state-by-state assessment of precollege mathematics and science education. This assessment would obtain information pertaining to teacher salaries, qualifications and loads; graduation requirements, teaching and laboratory equipment, instructional time and student performance.

RESOLUTION C

Because public support and encouragement are essential components for improving science and mathematics education,

CSSP member societies and their regional sections are encouraged to use their good offices in recognizing and publicizing award-winning science and mathematics teachers, such as those honored in the Presidential Awards Program.

RESOLUTION D

If the United States is to increase its technological competitiveness, it is imperative that science and mathematics education be extended to the increasing number of students who have been historically at risk. The CSSP recommends that a program, similar to the Presidential Awards Program for Science and Mathematics Teachers, be created to identify and recognize educators who have had exceptional success in teaching and motivating students who have been historically at risk in mathematics and science.

RESOLUTION E

The CSSP encourages its member societies to bring the knowledge and beauty of science and mathematics to K-12 students, to make them realize the importance of science and mathematics in their daily lives, and to ensure a scientifically and mathematically literate citizenry.

COUNCIL OF SCIENTIFIC SOCIETY PRESIDENTS

Council of Scientific Society Presidents

RESOLUTION

Minority Participation in the Scientific Professions

The current level of minority participation in the scientific profession is inadquate. The Council of Scientific Society Presidents believes it should be increased and encourages its supporting societies to work on increasing the number of minority participants by:

1. increasing efforts to recruit underrepresented minority students into graduate programs in mathematics and the sciences;
2. increasing efforts to recruit underrepresented minority students into undergraduate programs in mathematics and the sciences; and
3. encouraging greater participation by minorities in mathematics and science education at the precollege level.

CSSP/hmf
11/30/87

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The views expressed by CSSP are those of its members and do not
necessarily represent the official position of their respective organizations.

RESOLUTION

The Council of Scientific Society Presidents supports in principle the concept of the scholarship program as proposed by Congressman Walgren:

> "This bill (H.R. 5518) would create Congressional awards for science and engineering (CASE), modeled in part on the Congressional appointments of young men and women to our military academies. The awards would be 4-year fellowships, based on merit and a competitive selection process, for study in science and engineering at a U.S. undergraduate institution of the student's choice. Two such awards would be made every year in each Congressional district--one to a young man, the other to a young woman--ensuring opportunity to bright students from all corners of the country." (Congressional Record E 3404, October 12, 1988)

The CSSP would also be willing to assist with support activities such as cooperating as needed with the National Science Foundation, providing advice regarding the administration of the program, and in encouraging our societies and society members to support the program at the local level.

CSSP/hmf
12/7/88

CSSP
RECOMMENDATIONS ON SCIENCE POLICY
for the New Administration and Congress

The common defense and general welfare of the nation depend increasingly on strong science and technology. In order to enhance the contributions that science can make to our national agenda, the Council of Scientific Society Presidents urges the new Administration and Congress to take the following actions:

I. IMMEDIATELY APPOINT A SCIENCE ADVISOR TO THE PRESIDENT

- The Science Advisor should have regular and meaningful interactions with the President on all matters pertaining to science and technology.
- Effective linkage should be established among the Office of Science and Technology Policy, the National Science Board, the National Institutes of Health, the Office of Technology Assessment, and other organizations dealing with science and technology policy.

II. STRENGTHEN SUPPORT FOR SCIENTIFIC RESEARCH

- Basic research activities stimulate both scientific knowledge, which is essential to a healthy economy, and the apprenticeship education of new scientists and engineers, who are essential for teaching, research, and industrial leadership.
- Appropriations for the National Science Foundation should be doubled within five years, as presently authorized.
- To assure broad scientific strength, research activities of other appropriate federal agencies (the National Institutes of Health, the Departments of Agriculture and Energy, the Food and Drug Administration and the Environmental Protection Agency) should be increased also.
- Special action is needed to help universities and colleges provide adequate up-to-date research and instructional facilities.
- It is important that the capacity for research be strengthened in each region of the nation.

III. ASSURE QUALITY MATHEMATICS AND SCIENCE EDUCATION FOR ALL STUDENTS

- There is a special need for support at those levels where career decisions are made and future teachers are educated, especially for underrepresented groups.
- The Federal government bears principal responsibility for continual evaluation of the status of science and mathematics education.
- Federal leverage in education is most effective when it is used to identify and disseminate information about successful programs.

IV. ENCOURAGE FREE FLOW OF SCIENTIFIC INFORMATION

- The best information policy is one that imposes the least possible restrictions.
- Legal protection of intellectual property rights is an essential stimulus to the free flow of scientific information and technology transfer from the laboratory to society.
- Strengthening of national and international programs that promote exchange of scientific information is important to insure progress in basic scientific research.

V. REAFFIRM THE PRINCIPLE OF SCIENTIFIC MERIT AS THE PRIMARY BASIS FOR REVIEW OF RESEARCH PROJECTS AND FACILITIES

VI. SUPPORT MEASURES TO PROTECT THE ENVIRONMENT FROM HUMAN ACTIONS THAT MIGHT IRREVERSIBLY REDUCE THE QUALITY OF LIFE

- Ocean pollution, deforestation, loss of biological diversity, habitat destruction, acid rain, soil and water contamination, ozone depletion,and buildup of carbon dioxide and other greenhouse gases are global problems that require international action before their effects become irreversible.
- Research and education programs that enhance our understanding of threats to our environment should be strengthened.

Unanimously adopted by the Council of Scientific Society Presidents,
December 7, 1988

by Bryan Kocher, acm President

president's letter

Encouraging the Good/Discouraging the Bad

The 101st United States Congress faces two proposals of considerable interest to all scientists. One proposal will encourage the best of our secondary school students to pursue higher education in science and engineering. This proposal is very good. The other proposal could severely restrict the amount of money that ACM and other scientific societies are willing to spend on journals like this, which will crimp the flow of information to scientists all over the world. This proposal is very bad. I want to encourage you to help promote what is good for science and to discourage what is bad.

Congressman Doug Walgren of Pennsylvania is the author of a bill (H.R. 5518) which would create a scholarship program called Congressional Awards for Science and Engineering (CASE). The CASE program would award two scholarships in each congressional district, one to a male and one to a female student, for higher education in science and engineering. The awards would be four-year fellowships, at about $5,000 per year. Each CASE would be based on merit and a competitive selection process. Winners would matriculate at the U.S. undergraduate institution of their choice, but would be obligated to pursue a degree in science or engineering. This program would be administered in much the same way as congressional appointments to the U.S. military academies.

The CASE concept was endorsed by the Council of Scientific Society Presidents (CSSP) at its December meeting in Washington. I hope that you will also support this beginning step in encouraging the most promising young people in the United States to pursue careers in science and engineering.

Representative Jake Pickle of Texas, Chairman of the House Ways and Means Committee's Subcommittee on Oversight introduced a set of proposals (request for comments 63 DER G-5, 4/1/88) to change the rules concerning Unrelated Business Income Tax (UBIT) for not-for-profit organizations, such as ACM. Unrelated business income is defined as income not derived from activities substantially related to an organization's exempt purpose. The new rules proposed by Representative Pickle cover more than two pages and contain only fifteen words that would significantly affect ACM. The section reads:

> "J. Apply UBIT to advertising income and allow deductions from UBIT only for direct advertising costs."

Publishing *Communications* costs almost $2.8 million per year. Other than the amount of your dues allocated to *Communications*, revenues are $1.7 million per year, $1.2 million from advertising, and $500,000 from other sources (principally nonmember subscriptions). The difference between total costs and revenues is made up by your membership dues—$1.1 million each year. ACM is committed to using the increasing advertising revenues of *Communications* to improve the quality of this publication. If the UBIT proposal is enacted into law, about $660,000 (advertising revenues less direct expenses of the advertising) would become taxable. For the first time, there would be a tax of about $225,000 on a journal that doesn't make money. This tax would mock the spirit of the income tax, which is supposed to match the tax burden with the ability to pay. Just to maintain the current level of quality under the new rules, membership dues would have to increase by nearly $4!

If membership dues were increased, our membership would surely fall; fewer computer scientists would read this journal and other ACM publications. If quality or content are cut to make up the difference, computer scientists will be able to share less information; significant work may go unpublished and unknown. Any way you look at it, if the rules are changed, the sum total of computer science knowledge decreases. Decreasing the total of scientific knowledge in the United States cannot be good for the nation. This proposal works directly against the intent of the CASE proposal.

Your help is needed to make something good happen and to keep something bad from happening to science and engineering. Support of H.R. 5518 will give a boost to science and technology education. Opposition to the UBIT advertising revenue changes will prevent major harm to the primary channel for communicating scientific and technical knowledge.

On December 7, I visited my congressman's office in Washington, D.C. and apprised him of my interest in these issues (and section 1706).

I urge you to write to your representative and, in your own words, encourage your member of congress to support Doug Walgren's CASE (A.R. 5518) and to oppose Jake Pickle's proposed change to UBIT on advertising revenue (request for comments 63 DER G-5, 4/1/88).

American Chemical Society

1155 SIXTEENTH STREET, N.W.
WASHINGTON, D.C. 20036

A "Comment" submitted by Monte C. Throdahl, Chairman of the American Chemical Society Joint Board-Council Committee on Chemistry and Public Affairs, to Chemical & Engineering News for anticipated publication in the March 20, 1989 issue.

A rare opportunity has arisen for ACS members to contribute effectively to consideration of a proposed -- and potentially very valuable -- new federal program for education in science, mathematics and engineering.

On Feb 9th Congressman Doug Walgren (D-PA) announced that he has submitted HR 996. Under this bill,

> "... the National Science Foundation would establish an annual merit-based competition for selecting one young man and one young woman from each Congressional district to receive a four year scholarship to pursue undergraduate education in science, mathematics or engineering. NSF would establish broad-based local committees of educators, scientists, mathematicians and engineers to submit nominees for these national awards. Students would be selected on the basis of their potential to excel, and their motivation to pursue a career in science, mathematics or engineering fields. Scholarships would be up to $5000 per year, and would be used for tuition, fees, and room and board expenses."

As of filing time, at least 35 other Members of Congress had joined in cosponsoring the Walgren bill, and several others are expected to do the same. Concurrently, Senator John Glenn (D-OH) has sponsored identical legislation (S-134) in the Senate.

The Executive Board of the Council of Scientific Society Presidents has gone on record in support of this legislation, and has suggested that its member organizations inform their individual scientist-members of its merits. Each individual scientist will then be in a position to provide information and assistance to her or his Representative and Senators, if they desire it. Then, the lawmaker may be interested in cosponsoring this legislation.

Having studied the Walgren-Glenn legislation, and having discussed it with Congressional experts and ACS officers, I'm convinced that the program it proposes would be of great value to our country. President Bush endorsed the concept in his recent address to the Congress, and received hearty applause.

Moreover, the cost -- $5 million dollars the first year and $20 million a year after four years -- would be a pittance when compared to the benefit of having hundreds of additional young U.S. men and women earning baccalaureate degrees in science, mathematics and engineering.

that is threatening our nation. We are in desperate need of such initiatives, and members of the American Chemical Society can help in make this one a reality.

I think that assisting one's Representative or Senators in appreciating the merits of the Walgren-Glenn legislation is a classic example of an exercise in responsible and meaningful public service in which scientists all too seldom have an opportunity to participate.

Monte C. Throdahl
Chairman, CCPA

FEDERATION OF BEHAVIORAL, PSYCHOLOGICAL AND COGNITIVE SCIENCES

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March 1, 1989

The Honorable Robert Torricelli
317 Cannon House Office Building
Washington, D.C. 20515

Dear Congressman Torricelli:

The Federation of Behavioral, Psychological and Cognitive Sciences is an organization of fourteen scientific societies and more than 100 university departments and research centers. I am writing on behalf of the Federation to let you know of its strong endorsement of H.R. 996, the "Congressional Scholarships for Science, Mathematics, and Engineering Act." It is challenging to prepare wisely for future requirements when pressure to fulfill current demands is intense. Chairman Walgren's bill is a welcome example of farsightedness. Few contest that advances in science and technology are building blocks of national prosperity. It is, therefore, in the national interest to assure an adequate supply of scientists, mathematicians and engineers. We are especially pleased with Congressman Walgren's approach to meeting this need. His bill provides an avenue by which members of Congress and other leaders in Congressional districts can participate directly in improving the knowledge base of the country. Modelled after the service academies nomination process, H.R. 996 would permit worthy district candidates to pursue undergraduate majors in a field of science or engineering. The decline of applicants for graduate study in some areas of science suggests that this is the right time to make a special investment in the undergraduate education of potential scientists and engineers: The investment will help return graduate applications to needed levels.

The March issue of *Federation News* will introduce the bill to Federation members. The *News* reaches approximately one third of the graduate departments of psychology in the country directly. Through the fourteen scientific societies of the Federation, it also reaches many other educators and researchers.

We are heartened that more than half the members of the Science, Space and Technology Committee joined Congressman Walgren as original cosponsors of the bill. Our hope is that all members of the Committee will cosponsor the bill and will recommend it for passage to the full House as early as possible in the 101st Congress.

Sincerely,

David Johnson, Ph.D.
Executive Director

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Mr. **Walgren**. Dr. Malone.

STATEMENT OF DR. THOMAS F. MALONE, PRESIDENT, SIGMA XI, THE SCIENTIFIC RESEARCH SOCIETY AND SCHOLAR IN RESIDENCE, ST. JOSEPH COLLEGE, WEST HARTFORD, CT

Dr. **Malone**. Thank you, Mr. Chairman.

In view of the time, I will stand on my prepared statement, which sought to set out the reason this venerable honor society is mobilizing its 110,000 scientists, engineers, and mathematicians in 500 chapters and clubs to get behind the step that you have so credulously set forth.

I tried to spell out the stark statistics which undergird that concern, that the flow of creative young minds into science and mathematics that undergird our economic well-being is drying up.

I made recommendations. I sketched out some of the larger picture, described some of the things that we in Sigma Xi are doing with our own funds to complement and extend your efforts.

It seems to me that this exciting hearing this morning focuses in on three problems that I think are uppermost in your mind.

One is what can you and the NSF do on curriculum development, on teaching—that is, cloning the Dr. Saltman. I thought he was just tremendous—and, third, the issue that Dr. Boyer raised about a Manhattan project. I yield to no one in my admiration for Dr. Boyer, but I am not certain that a Manhattan project is the best way to go.

I would simply invite your attention to Attachment D in my prepared testimony, which is a set of pie charts portraying the waxing and waning of the allocation within the National Science Foundation for their Science and Engineering Education Directorate, and it is that chart that I believe should receive the very thoughtful attention as you prepare a response to the issues that have been raised here this morning.

It is not, in my opinion, a Manhattan project, but a sustained program which goes over many, many years that will get at the fundamental problems brought forth in the superb testimony this morning.

This may be an historic moment. As I look around this room, I have been privileged over a quarter of a century to testify before each one of these chairmen. I couldn't help but thinking this morning that what you are about here may be the first step analogous to the far-sighted and courageous move our nation made in what was perhaps its darkest hour, the initiation of the Land Grant College Program back in the 1860s.

I am not saying it is the same. I am saying they were addressing a national problem. You are addressing a national problem, too, and I think you have taken a very important step, and the other bills are supportive of that.

I would simply encourage you to think of what was done 125 years ago and see if you can build on this important step and accomplish in the long run what has been accomplished over the last 125 years.

Finally, since Dr. Atkinson raised the question, I think some designation would be helpful. May I venture the thought that Jefferson Scholars might be appropriate? I yield to no one in the idea of Walgren Fellows, but I know how modest you are, Mr. Chairman. [Laughter.]

And I am prompted to do that by a remark that President Kennedy made one time when he had a bunch of National Academy people together, and he said, this is the greatest assemblage of minds since Thomas Jefferson dined alone in the White House.

The name "Jefferson" might help to convey the excellence which should be the hallmark of this program.

Thank you, Mr. Chairman.

[The complete prepared statement of Dr. Malone follows:]

SUMMARY TESTIMONY

by

Thomas F. Malone
President, Sigma Xi, The Scientific Research Society
Scholar in Residence, St. Joseph College, West Hartford, CT

before the

SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY

during Oversight Hearings on the

National Science Foundation

March 9, 1989

Room 2318, Rayburn House Office Building
Washington, DC

Our grass-roots Honor Society with 511 Chapters and Clubs in every State of the Union (Attachment A) and 108,000 active members from the natural sciences, engineering, mathematics and the social sciences (Attachment B) -- elected in recognition of their research accomplishments -- strongly supports H.R. 996, Congressional Scholarships for Science, Mathematics and Engineering.

Our Centennial Observance in 1986 focussed the attention of Sigma Xi on scientific and technological opportunities and contemporary issues of science and society. Among our major concerns is a continuing flow of gifted young men and women into teaching and research in order to assure a scientifically literate public and a vigorous and productive research enterprise. We are persuaded that our nation faces a crisis in both of these areas for which we have some shared responsibility. I speak for an overwhelming number of members in stating categorically that H.R. 996 is a uniquely positive step necessary to respond to this crisis. Its importance transcends the self interest of the research enterprise and bears directly on our nation's social and economic wellbeing.

While there are many dimensions to the problem of attracting gifted young people into science and technology, Sigma Xi has focussed on the role of the undergraduate educational experience of our young men and women. At a meeting, of a National Advisory Group on this topic, we convened in Racine, Wisconsin, in January, Kenneth C. Green, Associate Director of the Higher Education Research Institute at UCLA shared with us some ominous figures mostly developed under the auspices of the American Council for Education. Of special importance were the following:

+ From 1968 to 1989 freshmen interest in fundamental undergraduate science and mathematics declined by almost 50 per cent; in physics, the drop was more than 50 per cent; in mathematics, it was 80 per cent; interest in biology remained relatively stable.
+ Freshmen interest in technological careers declined by 25 per cent between 1982 and 1986.
+ Freshmen planning careers as computer professionals declined by 75 per cent between 1982 and 1986.
+ More than one-half of the academically able students entering college and planning to pursue science majors changed to non-science fields; nearly 40 per cent of first-year college students with science and engineering interests ultimately take degrees in other fields (Attachment C).
+ Today very few aspiring science and mathematics majors plan to pursue careers in high school teaching.

These figures are ominous. They literally cry out for action. No single step will suffice. H.R. 996 will be an important and tangible manifestation of the value our nation places on a solid core of creative young men and women prepared to develop and apply the knowledge that is crucial as we approach the Third Millennium. The interest of President Bush in this issue is heartening.

With respect to H.R. 996, I recommend:

- NSF is the most appropriate home in the federal government for this activity.
- This and related activities should be consolidated in the Directorate for Science and Engineering education as proposed by the National Science Board Task Committee on Undergraduate Science and Engineering Education in March, 1986.
- The authorization of $5.5 million for the fiscal year 1990 as recommended in H.R. 996 should consist of "new" funds, rather than being provided by a reallocation of funding within the total NSF Budget.
- The FY 90 request for $190 million for the SEE Directorate should be increased at least to the $205 million proposed by the NSF Authorization Act of 1988.

For its part, Sigma Xi is planning to expand its program of Grants-in-Aid of Research which currently provides over $400,000 annually to more than one thousand young men and women at the predoctoral level interested in research careers. Much of this support comes from membership dues. We are cooperating with the NSF in National Science and Technology Week and are collaborating through our chapters and clubs with the AAAS in their joint program with Science Museums. We work with the Boston Museum of Science in their Science-by-Mail Program.

In an effort to stimulate popular interest in these matters, we arranged an International Symposium in Orlando, Florida, last October, addressed to Public Understanding of Science and Technology. We have activated our 511 chapters and clubs to exercise their influence at the local level in improving the sad state of affairs that presently exists in this matter.

We have underway other steps. The report of the meeting our our National Advisory Group to explore the nature and quality of Undergraduate Education in Science, Mathematics and Engineering will soon be available. Among the other recommendations, it will urge:

+ Penetrating discussion and evaluation of the factors that make the reward system for excellence in undergraduate education noncompetitive with other professional activities of sciences, mathematicians and engineers,
+ scholarly research related to education at the undergraduate level,
+ the development of more appropriate entry level undergraduate courses in science, mathematics and engineering for those professionally oriented in those subjects and also, as a separate stream, for those who need a more general orientation in those topics,
+ development of process oriented laboratories for all students at all levels in science, mathematics and engineering,

+ participation of majors in science, mathematics and engineering in student research,
+ facilitation of the entry and sustained professional development of women, minorities and disabled in science, mathematics and engineering,
+ the exchange of information among those developing innovative undergraduate curricula.

These action items complement and support the objectives of H.R. 996. They suggest that it may be timely to restore, at least in part, the emphasis accorded science and education within NSF (Attachment D).

Finally, I can say that our Society is prepared to tap the enthusiasm of our members for volunteer activity to assist the National Science Foundation in implementing the imaginative program proposed in H.R. 996. (Attachment E) The guest editorial by Congressman Walgren in the September-October 1988 issue of the American Scientist (Attachment F) in which he described the initiative now embodied in H.R. 996 generated an enormous amount of enthusiasm among our members.

Biographical Note --

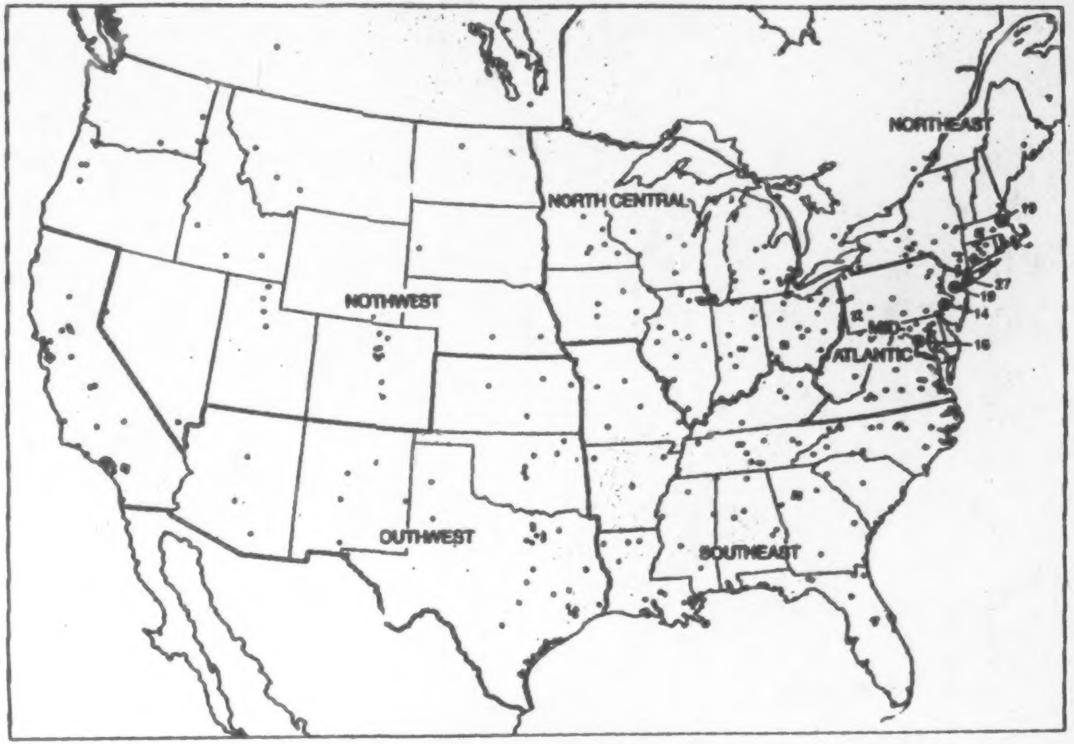
Reared in South Dakota, Dr. Malone holds a baccalaureate degree and an honorary Director of Engineering from the South Dakota School of Mines and Technology.

He has held tenured academic appointments at M.I.T. (when he received his earned doctorate) and at the University of Connecticut (where he was also Dean of the Graduate School). He is Director Emeritus of the Holcomb Research Institute of Butler University, Indianapolis, IN. A member of the National Academy of Sciences, he served as its Foreign Secretary, 1978-82. He is a past President of both the American Geophysical Union and the American Meteorological Society. He holds the position of Executive Scientist in the Connecticut Academy of Science and Engineering.

ATTACHMENT A

SIGMA XI: A GRASS ROOTS ORGANIZATION

More than 500 local organizations with 115,000 members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Testimony of Dr. Thomas J. Malone
President of Sigma Xi: The Scientific Research Society

Subcommittee on Science, Research and Technology of the House
Thursday, March 9, 1989

ATTACHMENT B

DISCIPLINARY AFFILIATION OF SIGMA XI SCIENTISTS AND ENGINEERS

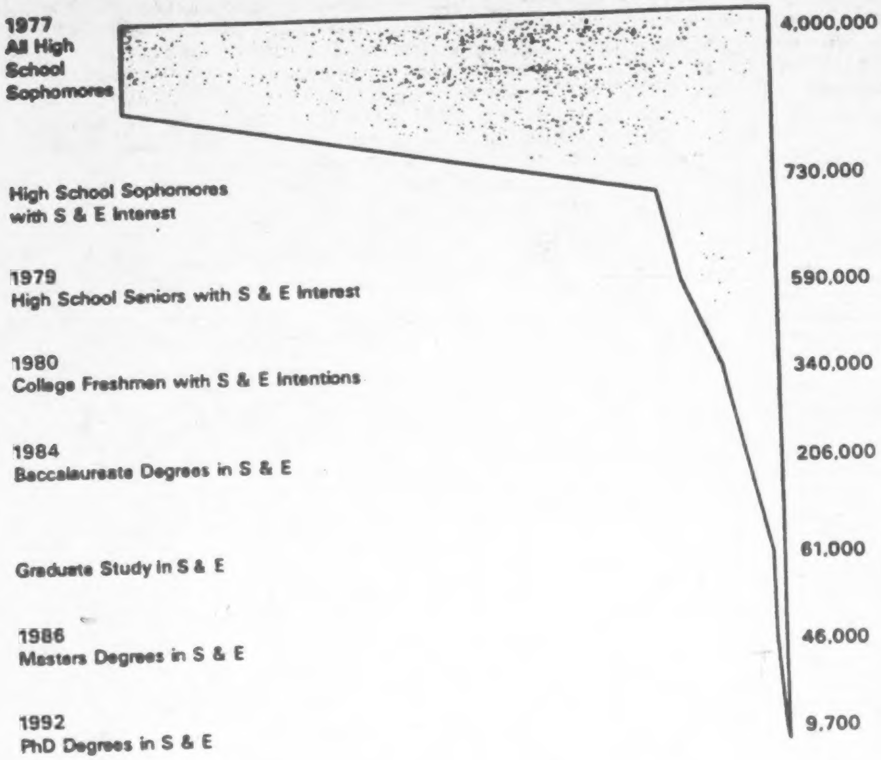
Membership in Sigma Xi, when considered by field of science, as reported in the 1988 Survey of Scientists, approximates the "Employed Doctoral Scientists and Engineers by Field: 1977-1987" as shown in the National Science Foundation distribution, "Selected Updated Charts and Tables for Science and Technology Resources Chartbook. This seems reasonable because nearly four-fifths of the Sigma Xi members have either a Ph.D. or an MD, and nearly nine-tenths reported they are employed. The remainder reported they are retired. The 1988 Survey of Scientists recorded 3.4% "No Answer"; these are distributed proportionally across the field categories.

FIELD	SIGMA XI MEMBERSHIP		NSF CHARTBOOK*	DIF
	Survey	Actual		Survey/Chartbook
Physical Sciences	26.0%	26.8%	20.6%	+5.4%
Biological Sciences	25.1%	25.3	14.8%	+10.3%
Engineers	21.6%	21.3	16.2%	+5.4%
Social Scientists	7.6%	6.7	29.2%	-21.6%
Medical Sciences	7.3%	7.7	7.1%	+0.2%
Agricultural Sciences	7.0%	7.2	8.0%	-0.2%
Math & Computer Sciences	5.4%	5.0	8.4%	-3.0%

*Sums to >100%, probably due to rounding.

ATTACHMENT C

Science & Engineering Pipeline, from High School through Ph.D. Degree

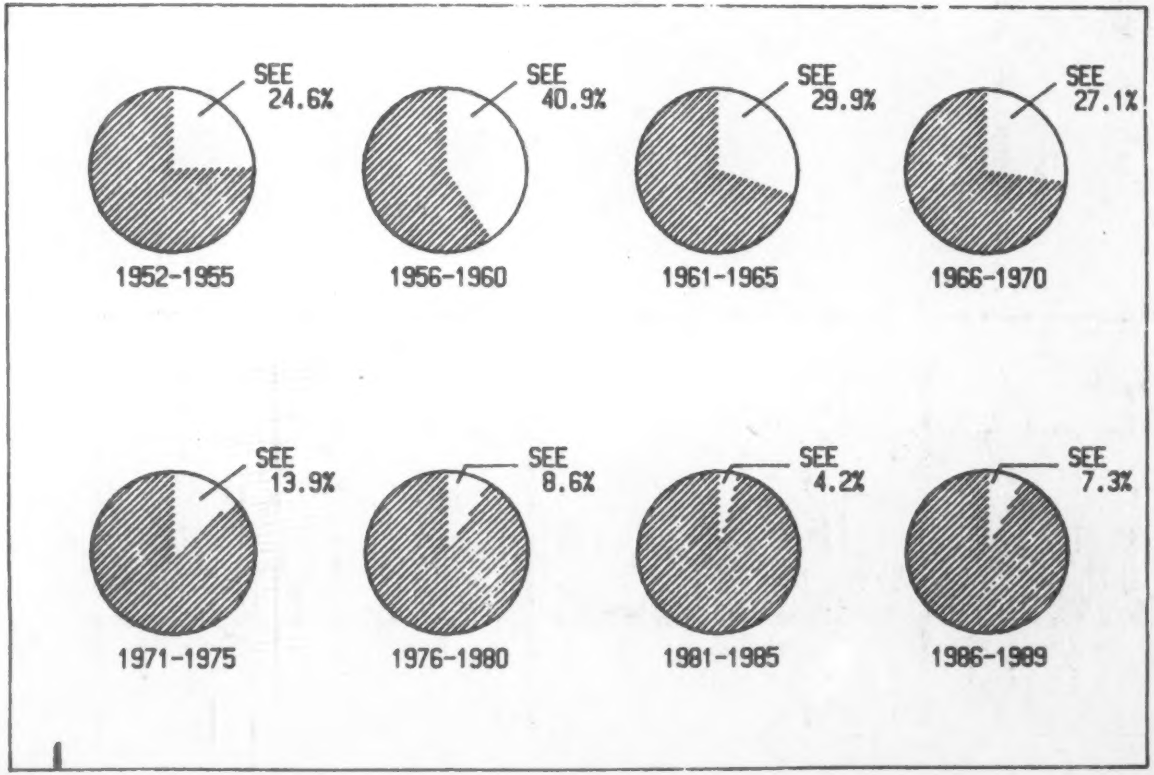


Analysis of the 4 million students in the 10th grade in 1977 shows the pattern of attrition as they move through the educational pipeline. Approximately 9,700 or 0.24 percent are expected to attain the Ph.D. in science and engineering.

Source: National Science Foundation.

ATTACHMENT D

Obligations for Science & Engineering Education
as percent of NSF Budget



ATTACHMENT E

VOLUNTEERISM AMONG SCIENTISTS

Some Results from Sigma Xi's

1988 Survey of Scientists

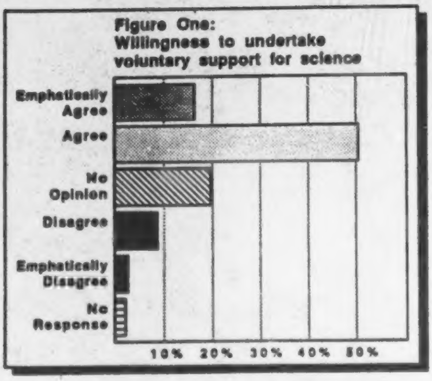


Figure One:
Willingness to undertake voluntary support for science

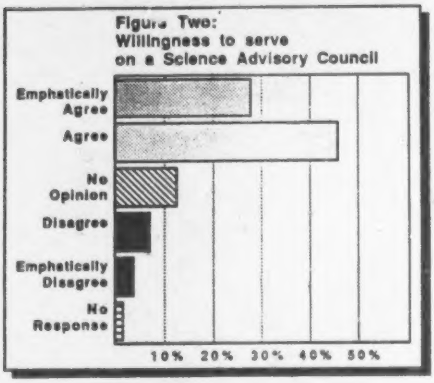


Figure Two:
Willingness to serve on a Science Advisory Council

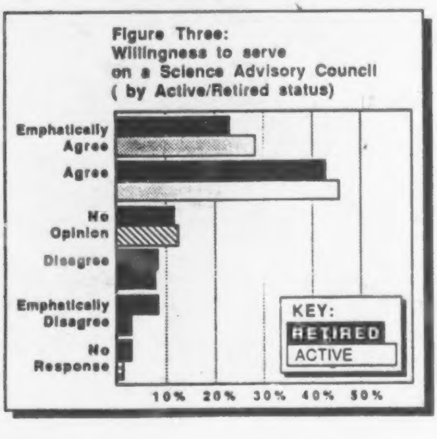


Figure Three:
Willingness to serve on a Science Advisory Council (by Active/Retired status)

Source:
1988 Sigma Xi:
Survey of American Scientists

ATTACHMENT F
SEPTEMBER-OCTOBER 1988

A Proposal to Congress and the Nation

As a nation, we are struggling to improve our ability to compete. A key element of competitiveness is our strength in science and technology—the ability to create new knowledge and apply it in new products. That in turn depends on our human capital—the quality and quantity of our scientists and engineers.

We cannot take the supply of scientific talent for granted. Relatively few high school students go on to get an undergraduate degree in science or engineering. Because of a 25 percent decline in the number of children born—a demographic trough in the US population—the pool of high school students will shrink in the decade ahead. Moreover, according to a study by the Office of Technology Assessment (*Educating Scientists and Engineers: Grade School to Grad School*; OTA 1988), the proportion of students entering college who are interested in studying science and engineering has declined over recent years. Taken together, these two trends foretell problems ahead.

Among options identified by OTA for dealing with the potential shortfall is the idea of targeted support for undergraduates who major in science or engineering. This is an unparalleled opportunity to offer substantial encouragement to talented young people—and at the same time to remind all of us of the importance of this human capital to our national security and our economic well-being.

Specifically, I propose that we create Congressional Awards for Science and Engineering (CASE), modeled in part on the congressional appointments of young men and women to our military academies. The awards would be four-year fellowships, based on merit and a competitive selection process, for study in science and engineering at a US undergraduate institution of the student's choice. Two such awards would be made every year in *each* congressional district—one to a young man, the other to a young woman—ensuring opportunity to bright students from all corners of the country.

Because of their broad geographical distribution, CASE fellowships would serve as a highly visible stimulus and source of role models for high school students—especially if, as we hope, the fellowships come to symbolize the national stake in science and engineering. The awarding of these fellowships—perhaps during National Science & Technology Week—would remind members of Congress and the public of the importance of science to our national goals.

Sigma Xi has a presence in each congressional district. Such an organization, with its interdisciplinary and grass-roots characteristics, would be an excellent mechanism for screening applicants. The awards could be funded through the National Science Foundation, where they would help the Foundation meet its mandate to strengthen science and engineering education, while ensuring improved geographical distribution in its programs. And it is important to add that the CASE fellowships would come from new money provided to the NSF and not come at the expense of any present program.

The cost of this kind of program is well within our means, and it is hard to imagine money better spent. As I conceive it, CASE would award roughly 870 new scholarships each year at an annual stipend of $5,000 each. The award would be an incentive meant to attract additional financial aid from other sources as needed by the student. When fully operational, the program would provide approximately $18 million in scholarship funds each year.

Through its visibility and example, however, the program would accomplish far more—providing a local focus on science and engineering education throughout the United States and signaling congressional support for meeting the critical national need for scientific talent.

The Honorable Doug Walgren
United States House of Representatives

Doug Walgren, Democrat of Pennsylvania, is chairman of the Subcommittee on Science, Research, and Technology of the House Committee on Science, Space, and Technology.

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Tel.: 203-624-9883

Sigma Xi

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Sigma Xi, The Scientific Research Society, has been since 1886 the honor society of scientists. Its 115,000 members in North America and abroad belong to over 500 chapters on university campuses and in government and industrial laboratories. Election to Sigma Xi, made on the recommendation of members, recognizes research achievement and carries with it the opportunity to cooperate with other scientists in the activities of individual chapters.

Mr. Walgren. Thank you very much, Dr. Malone.

Well, he is also connected to the fire bell in the night, is that right, which may be just as important in terms of ringing the alarm.

What can be said about linking this thing to teaching payback?

Professor Steen, you indicated that you feel that there is a value in allowing these paths to develop quite without restriction. On the other hand, there certainly is a value involving people in teaching.

I guess my question would be if we really get the brightest, if we go through a merit selection process and really get the brightest, would that be who you would want for the teachers?

Not that the teachers shouldn't be the brightest, but if you really got one or two or four people out of a population of 540,000, does it then become more important to allow them the freedom of that track rather than ask those four to go back and teach, or is there some way that perhaps we can pick up a teaching component of this, too?

And, you know, I am trying to figure out how Sherry and I can really get together on this and have one package that accomplishes both our objectives.

Dr. Atkinson. Mr. Chairman, I like the service concept. When you look at the pipeline and particularly the issue of training Ph.D.'s in the natural sciences and engineering, you don't want to divert talented people who may go on to graduate programs and on to research off into, say, just two years of teaching as a payback. I think you have got to have some sort of flexible concept of service, and that might mean eventually becoming a faculty member in a university, but it——

Mr. Walgren. If we were to think that, number one, we don't know whether these people will go on to graduate school. Some would and some would not, but perhaps if they went on to graduate school that might fill some of Mr. Boehlert's values that he is looking for on the teaching side.

Dr. Atkinson. But I think even service while they are in college in a tutoring role or services graduate students in some type of tutoring role or going on to accept a faculty position.

There are a number of things that could be worked out, and I am not sure you should try to work them out. You might rely on a committee from NSF to really lay out what would make sense in terms of a service requirement.

Dr. Malone. Mr. Chairman, I believe that if the program is even modestly successful the payback to the country in terms of increased productivity will more than pay back the money, and I think that is a better way than trying to pinpoint it.

Mr. Walgren. Professor Steen.

Professor Steen. Let me just add, also, that as you have heard from other testimony, if your intent is to make a significant impact on the teaching needs of the nation, you would have to have many, many more than just a thousand a year.

Dr. Atkinson. But this will cascade, just the image associated with the public recognition, and that is why I want this not to be something where you hand a fellowship to a person and forget about it, but that somehow the person carries that fellowship and the pride of having won it right through, and so that there might be summer meetings of these fellows gathering in a region of the country. So there is an esprit de corps associated with that, and that will bring lots of other people along.

And then I think again it is clear that we all agree this is just one thing that should be done, but we are very enthusiastic about this one item.

Mr. **Walgren**. Well, I am just sort of fishing for flexible ways to pursue the teaching value that Mr. Boehlert is looking right at and yet not confine the path these people take absolutely.

Do we have any experience with penalties, as such?

Mr. Boehlert's proposal envisions an actual penalty if the individual fails to fill the teaching commitment over and above the amount of the loan, in truth.

Do we have any experience with anything like that?

We have had forgivable loans, I gather, so that you earn your way out of an obligation, but what about penalties per se?

Professor **Steen**. Well, as I suggest in my written testimony, I think the image—if you are going to structure it that way, the image of the forgivable loan seems to be a better metaphor and a better structure than the image of a penalty for somebody who for perfectly good reasons may have changed their career plans. It is not something that one should consider to be a wrong that they have done. It may be very good for the country that they discovered that they could do tremendous good as a research biochemist rather than as a schoolteacher, and we shouldn't impugn their integrity for having done that.

Mr. **Walgren**. What can be said about the role that these nominating committees might play in regions in which they are located?

Dr. Atkinson, you suggested that they might be involved—I think it was your testimony—where they might be involved in generating some funds from a matching basis or from a community basis. There is a lot of potential in a committee that would actually work on these problems.

Dr. **Atkinson**. Tremendous potential. I mean, you draw together important people from the educational sector, from the public sector, from the private sector to make these decisions.

The committee might continue, with changing membership year to year. It would just draw a great deal of recognition to the issue, and that is why, in a way, I would like to have the Congressman from the district in some sense involved.

I don't want the Congressman to make the decision, but I also don't want the Congressman isolated from the decision.

So a representative of the Congressman or Congresswoman on the committee might be worthwhile, but I think again it is another part of this picture. It is an image. It is attention to these matters that is drawing people in the community to focus on it that will pay back in great dividends.

Mr. **Walgren**. It is interesting to think that something very flexible and creative could come from pulling together people to focus on these problems in their own communities.

Dr. **Atkinson**. Mr. Chairman, there I would want the Congressional member to issue the invitations to the committee, almost more so than some isolated individual in NSF.

I would like it to be a feeling that this is a very important thing that goes on in the individual's district and gets the appropriate sort of publicity in the newspapers and the like.

That is good for the Congressperson, but it is good for the students and teachers, and the like, who are concerned.

Dr. **MALONE**. There is a very powerful multiplying effect, yes.

Mr. **WALGREN**. Of course, it is also true that some Congress people would not be interested in this area. I mean, Congress people come from all walks of life and focus. I wonder whether we have to have some kind of fallback for this kind of program to go on on a nationwide basis, even if the individual Congressman may not want to give time to it or great personal effort.

Dr. **ATKINSON**. Well, obviously, if an organization like NSF ran this, it would operate with or without the Congressional person, but I would hope that NSF or whoever was running it would be so heavily biased that they would try to draw in the Congressperson and significant figures in the community so this has great visibility.

Mr. **WALGREN**. It is true that the highest military award is the Congressional Medal of Honor, and that historically, as I understand it, is the standing that Congressional awards can be measured by.

There is no military award given by the President of the United States. An award is given on behalf of what the Congress represents, which is the closest embodiment of the people as a whole.

So there is real reason for us to be pursuing Congressional awards in this area, I would think.

Dr. **ATKINSON**. Yes. Mr. Chairman, I like those remarks, and I guess I want to associate myself with my colleague here on the right.

I also like the service component in a way for many fellowships, and the like, but I see these as so specialized and hitting on such a unique group of people that I am not really quite sure that we have to worry about insisting on a service component to them.

I like the concept for the broad range of fellowships and programs that I think are going to have to be put in place, but I still see these Congressional fellows as so unique and so special that I might not worry too much about the service component.

But I think you have got some colleagues who may want you to worry about it.

Mr. **WALGREN**. Well, there might be a way to build some real incentives in to do the teaching component as well or perhaps make it flexible enough that that value could be satisfied regardless of what direct path people took.

What about the transition from undergraduate to graduate school for these people?

If they are properly selected, they will be the kind of person who will be doing graduate work.

The NSF of course has a program of graduate fellowships, and they are making a pretty good cut, as I understand it, picking the students that have the greatest potential evaluated at that point in time.

Mr. Slaughter suggests a program that would move the picking point of graduate support back a little bit, as I understand it, into the junior year, and one concern would be if you want to keep these monies targeted on the most meritorious at each point how do you mesh the NSF's graduate fellowship program with a program that would have a geographical distribution based on a junior year evaluation?

Professor STEEN. It is very difficult to assess a student's scientific or mathematical potential that early in their college career except in a few cases of very, very outstanding students.

But the first two years of undergraduate preparation are pretty broad and general, and the experience of being involved in undergraduate research and getting a sense as to whether students have the potential and interest to go on usually emerges in the junior and senior year.

Now, that doesn't mean one can't have programs at all levels.

I mean, there is very good benefit at the high school level and in the middle of the college career and at the beginning of the graduate career to have programs, but I would hate to see one replace the other.

Mr. WALGREN. I see.

Dr. MALONE. It seems to me the most critical time is the transition between the high school and the college. Only one out of three high school seniors interested in science and engineering go on to get their baccalaureate. If you build up that corps, you have provided a broadened base for the selection on Ph.D.'s, and if you have to conserve your resources, it seems to us that it is at the critical first year college level.

In our study of Wing Spread in January, we underscored the importance of new entry courses into science and engineering at the college level, first year. That is when they are turned on or turned off.

Mr. WALGREN. Well, all right, we are under some real pressure for the next committee that has to use this room, and I appreciate how far you have all come and that you have given us of your time, and perhaps we can develop some of these thoughts with you informally and get some good guidance from you after the hearing.

Thanks very much. We appreciate your being a resource to us.

[Whereupon, at 1:20 p.m., the subcommittee was adjourned, subject to the call of the Chair.]

OVERSIGHT OF THE NATIONAL SCIENCE FOUNDATION

TUESDAY, MARCH 14, 1989

House of Representatives,
Committee on Science, Space, and Technology,
Subcommittee on Science, Research and Technology,
Washington, DC.

The subcommittee met, pursuant to recess, at 9:37 a.m., in room 2318, Rayburn House Office Building, Hon. Doug Walgren (chairman of the subcommittee) presiding.

Mr. Walgren. Let me call us to order.

We begin our process of oversight hearings on the National Science Foundation's programs this morning.

Today's oversight hearing on the National Science Foundation will focus on three specific research programs of the Foundation, the first being research in the behavioral and social sciences; the second being research and facilities needs in astronomy; and third, research and support for research and environmental protection issues involved in the U.S. Antarctic program.

A previous oversight hearing of our committee on March 9 concentrated on NSF's pre-college science and mathematics education efforts, and on March 16 will we have NSF witnesses describing their plans and priorities as revealed in the proposed fiscal year 1990 budget.

The first two panels this morning on the behavioral and social sciences and on astronomy will talk about the issue of adequacy of support for research in their respective fields. Despite budget growth at NSF over the past several years, research programs in each of these two fields have grown little or at all, and we will be interested in hearing arguments in support of greater efforts for funding for research in these areas, including ways that that research contributes to the advancement of other fields of science and how it benefits and applies to each of us in our everyday lives.

We also want to invite the views of the behavioral and social sciences panel on whether current NSF programs are consistent with the potential for research, the research opportunities that were highlighted in the recent report of the National Academy of Sciences.

We want to invite the views of those on the astronomy panel on the priorities of new astronomical research facilities and, in particular, the priority that should be assigned to replacing the capabilities that were lost recently in the collapse of the radiotelescope in West Virginia.

The third panel this morning will address aspects of NSF's research and support for research in the Antarctic. Of particular interest is NSF's proposed initiative for fiscal year 1990 on the environment, health, and safety with respect to activities in the U.S. Antarctic program. We want to gather comments from the panel on the content and the resources allotted and the time scale that this plan encompasses.

We would also like to have the views of the panel on the objectives of NSF-sponsored research in the Antarctic and on the adequacy of the support that is provided for that effort.

On our first panel this morning on behavioral and social sciences, I want to express a particular welcome to Dr. Herbert Simon, professor of psychology at Carnegie Mellon University. I come from Pittsburgh, as many people know, and Dr. Simon has been such a wonderful part of our community, both at large and in our educational community, and it is a particular honor to have you come and share in our process today, Dr. Simon.

I also want to welcome to this panel Charles Schultze, the Director of the Economic Studies Program at Brookings Institution, who has been such a pillar of Washington comment over the years, and Mr. William Gorham, the President of the Urban Institute. We welcome you both and are glad you are here.

The next panel on astronomy—and I will introduce them just briefly—consists of Dr. Arthur Walker, the chairman of the National Science Foundation's Advisory Committee for Astronomical Sciences; Dr. Paul Vanden Bout, the Director of the National Radio Astronomy Observatory; Dr. Sidney Wolff, Director of the National Optical Astronomy Observatories; and Dr. Tor Hagfors, Director of the National Astronomy and Ionosphere Center.

Then on our last panel we will have, dealing with the U.S. Antarctic program, Mr. Robert Craig, the President of the Keystone Center; Bruce Manheim, representing the Environmental Defense Fund; and Dr. Rutford, the President of the University of Texas at Dallas, who was unable—I am sorry—to be with us this morning because of legislative commitments in his State, but he has submitted written testimony for the record, and that will be helpful to us.

Well, with that, let me recognize other members for opening thoughts that they would like to share with the committee, and, in the order of their appearance, let me recognize Mr. Brown of California first.

Mr. BROWN. Mr. Chairman, I have no opening statement, but I am pleased to welcome the distinguished witnesses we have this morning. I think we will benefit a great deal from their testimony.

Mr. WALGREN. Thank you, Mr. Brown.

Mr. Price?

Mr. PRICE. Thank you, Mr. Chairman.

I want to commend you for having these hearings on NSF oversight. Given recent studies that have shown significant problems in our Nation's educational system, I believe these hearings are both necessary and timely.

My own background in teaching and research is in political science, so I am especially pleased that you have decided to devote some of our time this morning to examination of NSF funding for the social and behavioral sciences.

These disciplines, just as much as the so-called harder sciences, are vital to our development as a society. They provide us the basic tools needed to grapple with, and prompt us to think more critically about, many of our current social problems. Certainly they deserve adequate levels of Federal funding.

Mr. Chairman, I welcome these hearings and look forward to the testimony of our witnesses today.

Mr. **Walgren**. Thank you, Mr. Price.

The gentleman from Virginia, Mr. Slaughter?

Mr. **Slaughter**. I have no statement, Mr. Chairman.

Mr. **Walgren**. Well, with that, let's begin.

I would only add that one of the first things that struck me in the 1980s was that the President of General Motors, on one of the national shows, and it was right in the throes of us essentially eviscerating and turning the coldest of shoulders on the behavioral sciences in the NSF, and I remember that the panelists on Meet the Press or something like that wanted to get him to comment on how burdensome all the regulations were and how much he looked forward and what his hopes were for the deregulation emphasis of what was at that time the new Reagan Administration.

His comment was, "You know, if I could get my people just to come to work half of the time that they now don't, all my problems would be solved." It struck me that there was something behavioral in that, and that certainly the forces that we deal with in the behavioral and the social sciences are so broad-spread in our society and so central to what we want to happen that the potential to make tremendous contributions to the well-being of the American venture are so strong in this area.

So we want to welcome you all here to talk about this part of the science agenda and underscore its importance at the same time. Let's start, and we will go through the panel in the order that I introduced you to the record, and we will start with Dr. Simon.

STATEMENT OF DR. HERBERT A. SIMON, PROFESSOR OF PSYCHOLOGY, CARNEGIE MELLON UNIVERSITY

Dr. **Simon**. Thank you, Mr. Walgren.

It is a very welcome privilege to testify here about NSF support for the behavioral and social sciences; from now on, I guess I will just call them the "social sciences" in the interest of brevity.

I have been involved for 50 years now in research in these fields, but that really is not my reason for thinking the Federal Government should support it. I want to say what kind of research is needed and why it is needed.

Basic science, of course, is aimed at finding out what the world is all about: what elementary matter is; the "big bang" and the origins of the universe; what life is, and its processes; how a brain can have thoughts; how our human societies work or do not work. The excitement of these big questions fuels the scientist and rouses the wonder and interest of all of us.

But, most important, science addresses the big problems we must deal with to survive and prosper in our world today: how to meet our needs for energy and other resources while preserving the environment of our planet; how to live in liberty, pursuing our happiness as individuals, and seeking peace in relation to other people and other nations.

We apply this term "science" to all kinds of inquiries, whether physical, biological, or social, because they all have the same foundation: a commitment to finding out, carefully and objectively, how things are and how they work. Science tries to replace guesses by fact. However varied their methods, the sciences are one in their commitment to the discipline of objective inquiry. And we need that inquiry as urgently in dealing with our social as with physical and biological facts.

The question is sometimes asked whether social science is possible. Well, it must be because it exists. If we don't always succeed in fine-tuning the economy—or, for that matter, our car—we still have vast knowledge of how an economy operates, and I think some of our other witnesses are going to have something to say about it. The economy, perhaps, is like meteorology: it is easier to understand the machinery of the weather than to forecast it or to change it.

We have much knowledge today of how the human mind thinks and learns, knowledge that helps us design, for example, our huge military personnel training programs, and "expert systems" that aid managers in our companies. We have much knowledge about the loyalties that bind people to their families, their organizations—that bring them to work in the morning, if they do—their nations, about what makes organizations efficient, about how people use transportation systems or fail to use them, about crime.

Much of the knowledge in the social sciences is common sense, but much of it flies in the face of common sense. Social science research educates our common sense, corrects it, expands it.

The research budgets for acquiring this essential knowledge have been pitifully small. The total annual Federal support for social science research, basic and applied, is about three-quarters of a billion dollars, which is, of course, a small fraction of the cost of a single laboratory instrument in physics, the supercollider.

The limited funding provides a wholly inadequate R&D backup for social programs, for society's programs, whose efficiency and effectiveness it is supposed to improve. Education, for example, costs nearly 5 percent of GNP; that is, if we do not charge any costs for the time of our student population. Even a 3 percent R&D budget for education would work out to nearly $5 billion a year, which is six times the level of support for all social sciences in the United States today.

Now, the main mission of the NSF is to support basic research, the rock on which applications build. Total Federal support for basic social science research in fiscal year 1987 was a little more than a quarter of a billion dollars. Of this, $52 million, plus or minus—we can argue about the exact boundaries—of this, $52 million, about a fifth, came from the National Science Foundation.

How have the social sciences fared in the NSF at budget time? Well, poorly. Severely cut in the early 1980s, as our chairman has mentioned, they have only now regained the levels then in current dollars. In constant dollars, they are now more than 30 percent lower than before.

You will see here the total budget for research in this country, the total NSF budget, the NSF behavioral and social sciences, the total research budget in the middle chart and the percent of behavioral and social sciences in the total Federal research funding from 1971 down to the present.

In constant dollars within the NSF, they are now more than 30 percent lower than before, while in the same decade, the NSF budget, in constant dollars, has been increased by 30 percent.

The fiscal year 1990 request, like all recent requests, proposes smaller increases, ranging from 7 to 10 percent, in all components of the social science programs than the 14 percent average increase proposed for NSF as a whole. Clearly, the National Science Foundation has had little vision of the important contributions the social sciences can make to our society, or of the exciting questions they are answering.

The many opportunities for valuable social science research, unexploited because of this stringency of funds, are amply documented by the recent National Research Council report on the behavioral and social sciences. The report identified specific areas of opportunity that call for new funding at a rate of $240 million annually. That is about one-sixth of 1 percent of our Nation's education budget.

About $60 million of that total belongs in the NSF budget, a little more than would be required to restore the social sciences to their 1980 share in that budget. To my mind, that is not nearly enough to exploit the opportunities that exist, but it certainly would be a substantial beginning and a great improvement over the present situation.

I cannot begin to summarize the 250 pages of concrete and specific examples of research needs the NRC committee identified. I trust that copies of its report have been provided to this committee. Those needs range over cognitive development; expertise, what makes an expert; the learning of science; reading; prevention of substance abuse; criminal careers and the criminal justice system; organizational evolution; bargaining and negotiation; technology, migration, and mobility; population change; international finance and domestic policy; superpower relations; and many others.

A few days ago I came across a simple but typical example of what social science research can teach us. Some 300 pregnant adolescents were followed up over a period of 17 years to discover how they and their children would fare. The study, which last year won an American Sociological Association award, contains a wealth of facts—not guesses but facts—and identifies specific factors "that distinguish adolescent mothers who successfully make the transition into adult responsibilities and those who do not."

Now, that is not a glamorous piece of research; it does not produce any sweeping new theories. But it does provide an invaluable factual background for public policies dealing with adolescent pregnancy, which is a major and growing social problem in our society.

Another example: Right now, in a classroom in Beijing, China, students are learning mathematics using a new method based on modern cognitive research that was carried out in an American university. I could tell you why the research was done in America and the teaching in China; that is another story. They are learning that mathematics in two-thirds the time required by their schoolmates who are studying by conventional methods.

However tentative the outcome, which does need further evaluation, it indicates what basic research is discovering about the mind and how close these new discoveries are to opportunities for important social applications.

These are just two examples with which I happen to be familiar. The NRC report which I mentioned describes hundreds of others at least as significant as these over the whole range of the social sciences.

I have focused my testimony on funding requirements and opportunities in the social sciences. I would like, in my written testimony, to append comments on three other not unrelated topics, and I would be glad to answer questions about them:

First, the need for better representation of the social sciences in the top administrative level of the National Science Foundation, which I would identify as a source of budgeting problems of the social sciences in that Foundation.

Secondly, the need for better social science instruction in the secondary schools.

And, third, the need for full utilization of the social sciences in the science education programs within the NSF.

I would also like to attach to the written record a statement which has been endorsed by 13 of the leading social science professional organizations on how we might go about implementing the recommendations of the NRC Committee on Behavioral and Social Sciences in the NSF.

I would be very pleased to answer any questions that the committee may have.

[The prepared statement of Dr. Simon follows:]

Testimony: Social and Behavioral Science Programs in the National Science Foundation

Herbert A. Simon

Department of Psychology
Carnegie-Mellon University

HRNSF.MSS

Testimony of
Herbert A. Simon

March 14, 1989

House Committee on Science, Space, and Technology

Social and Behavioral Science Programs in the National Science Foundation

It is a welcome privilege to testify here about the National Science Foundation's support of basic research in the behavioral and social sciences. Perhaps I should begin with a conflict-of-interest statement. I have been engaged for more than fifty years in social science research. (For brevity, I am going to use the phrase "social science" to cover all of the social and behavioral sciences.) From time to time I have received grants from the National Science Foundation, and it is not unlikely that I will again be an applicant for such a grant at some future date.

It will not surprise you that I am a strong advocate of social science research. Because of its intellectual excitement and its practical value, I have invested my life in it. It is an integral part of our great adventure into understanding the world, including -- perhaps most important of all -- understanding ourselves.

That is what basic science is about. We want to know the secrets of elementary matter; we want to know about the world's origins, the Big Bang and all that; we want to know about life, its processes and its chemical foundations; we want to know about mind, how a brain can have thoughts; and we want to know about our own human societies, their history and how they work.

Curiosity is a major driving force of science, and a noble goal. But how much funding could science claim on grounds of curiosity alone? Beyond curiosity, it is absolutely essential that we understand the world better in order to deal with the grave problems it presents: how to use the natural environment to meet our human needs while living in peace and equilibrium with that environment; how to live in health and liberty, pursuing our happiness as individuals and in our relations with each other -- individually, as groups, and as nations.

The reason why we apply the same name, science, to all kinds of inquiries, whether physical, biological, or social, is simple. Science means a commitment to finding out, as carefully and objectively as possible, how things are and how they work. Science warns us against basing our conclusions and our actions on guess when we could base them on fact. Although the sciences differ in the instruments and techniques they use; they do not differ at all in their commitment to the discipline of objective inquiry. And we have at least as urgent a need for that kind of objectively and discipline in dealing with social facts and laws as we do in dealing with physical and biological facts and laws.

The question is often asked, "Is social science possible?" It must be possible, because it exists. We have vast knowledge and understanding about the laws of economics, although not enough to manage a modern economy wholly dependably and smoothly. (We also have an enormous amount of knowledge about meteorology, but not enough -- a hundred years after Mark Twain -- to do anything about it, or even to predict the weather well.

We have a great deal of knowledge about how a human mind thinks and learns, knowledge that has already been drawn upon, for example, in the design of the huge and costly training programs that our military organizations must conduct, and of the "expert systems" and other aids to management that our companies require.

We have a great deal of knowledge about many other social phenomena: about human loyalties in different societies (to the family, to the work organization, to the church), about factors that determine organizational efficiency, about the workings of governments, about human responses to transportation systems, about crime. Some of it is "common sense," for we all live in the world and observe our fellow human beings and ourselves. But much of it flies in the face of common sense, because our casual observations are fragmentary, atypical, and biased by our beliefs and values. Social science research educates our common sense, corrects it and expands it.

We have acquired this knowledge in the social sciences with very modest research budgets. Total annual Federal support for social science research, basic and applied, is about three-quarters of a billion dollars. That still sounds like a lot of money to me -- until I compare it with the funds that are provided for other kinds of research (e.g., for a single instrument like the SSC), or, more important, until I compare it with the funds our society spends on activities that could be carried out more cheaply and effectively if we understood them better.

Primary and secondary education in the United States takes nearly five per cent of our GNP -- even if we treat students' time as a free resource to be used or wasted at will. Suppose we were to decide that some funds should be devoted to research and development so as to increase the educational return on this enormous expenditure (to improve our teaching of science and mathematics, say). Suppose we were to commit a modest three percent for this purpose; that works out to about 4.5 billion dollars per year -- six times the level of support for *all* social science research in the United States today!

Let me turn specifically to the National Science Foundation. Its main mission is to support basic research -- the rock on which important applications must build. Total Federal support for basic social science research in fiscal 1987 was a little more than a quarter billion dollars ($272 million -- approximately the "downpayment" for the SSC in the Administration's proposed budget). Of this total, $52 million, about a fifth, came from the National Science Foundation (these numbers exclude neuroscience, which is a biological rather than a behavioral or social science).

Thus, NSF is extremely important to the health and progress of the social sciences. How have they fared at budget time? Poorly. Their budgets were severely cut in the early 1980's, and only now have regained the levels, in *current* dollars, that they had reached in 1980. In constant dollars, they have declined more than 30 per cent in the decade -- a period in which the total NSF budget has grown some 30 per cent in *constant* dollars. The FY 1990 request, like all recent requests, proposes smaller increases (about 7 to 10 per cent) in all components of the social science programs than the 14 per cent average increase proposed for the NSF as a whole. Clearly the National Science Foundation has little vision of the important contributions the social sciences can make to our society, or of the exciting questions they are answering.

The many opportunities for productive research that remain unexploited because of this stringency of funds is well documented in the recent National Research Council report on the Behavioral and Social Sciences. The report identifies specific areas of opportunity that require expanded support, primarily in basic research, and prices out the cost of providing this addition funding at $240 million annually. Using my previous yardstick, that is one sixth of one percent of our country's annual budget for primary and secondary education.

The committee estimated that $60 million annually of this total could be assigned appropriately to the NSF budget, a little more than would be required to restore the social sciences to their 1980 share in that budget. To my mind that is not nearly enough to exploit the opportunities that exist, but it would be a substantial beginning.

I can't begin to summarize here the 250 pages of concrete and specific examples of research opportunities that the committee identified. A mere recital of some of the items in the table of contents is enough to show the intellectual excitement of the field and its significance to our society: early cognitive development and learning; expertise and scientific education; reading; prevention of substance abuse; criminal careers and the effects of the criminal justice system; setting agendas; organizational evolution; bargaining and negotiation; technology, migration and mobility; evolution of language; population change in developing countries, the nuclear family and social change; international finance and domestic policy; superpower relations.

Let me turn from the general to the very specific. Our newspapers and periodicals are full of discussions of the problem of the adolescent unwed mother. But what do we really know about it, beyond some very gross statistics on the annual number of births to such mothers? What becomes of these girls and young women, and what becomes of their children? What factors influence the outcome? What are the costs to society and what are the consequences?

Some years ago, some young social scientists at the University of Pennsylvania set out to answer these questions. Their project represented the most difficult of all research tasks -- keeping track of a sample of human beings (many of them on the margins of society) over a period of 17 years. They did it successfully, with 300 subjects, and their study, which last year won The William Goode Award of the American Sociological Association, contains a wealth of facts -- not guesses or conjectures, but facts -- that begin to answer the questions raised above. And their facts were less than obvious. For example, in the words of one reviewer, "the research demonstrates . . . that there are systematic, identifiable factors that distinguish adolescent mothers who successfully make the transition into adult roles and responsibilities from those who do not," and describes what these factors are.

Not a glamorous piece of research. No sweeping new theory has emerged from it, but just the kinds of hard facts that we need in order to understand adolescent pregnancy and to address the problems that it creates for both the actors and society. Here is a specific example that I ran across in my reading a few days ago, which illustrates the workaday world of social science, something of its intellectual excitement, and something of its importance.

But there is also theory in social science. For example, very exciting theories have been emerging to explain how the human mind learns, and what it contains when it has learned. Right now, in a high school in Beijing, China, a classroom of students is learning mathematics using a new method but a standard curriculum, and is learning in two-thirds the time required by their schoolmates using the standard method of lectures and problems. The new method was derived from a theory of "learning from examples," a theory that, in turn had been developed and tested at an American University by simulating the human learning with a computer program. This one experiment needs further careful evaluation; but, however tentative the outcome, it indicates what we are learning about the mind, and how close the new learning is to important opportunities for application.

These are just two examples with which I happen to be familiar. The NRC report mentioned above describes hundreds of examples, at least as significant as these, over the whole field of the social sciences.

I have focused my testimony on funding requirements and opportunities in the social sciences. I should like to append some comments on three other, not unrelated, topics: (1) the need for better representation of the social sciences in the top administrative levels of the National Science Foundation, (2) the need for better social science instruction in the secondary schools, and (3) the importance of participation of social scientists in the science education programs of NSF. I should also like to comment on the advocacy by ~~the~~ professional organizations of social scientists, on [illegible] by the NAS Commission [illegible] Behavioral and Social Sciences Research in the NSF.

Organization of the NSF

I have commented on the weak advocacy for funding social science research in the National Science Foundation as reflected in budget levels. At least part of this history can be understood in terms of the NSF organization. The social sciences represent a large part of the title and a small part of the budget of the Biological, Behavioral, and Social Sciences Directorate in the Foundation. The Assistant Director of that Directorate is, and has been, a biologist, as is the director of the Division of Behavioral and Neural Sciences.

Thus there are no social scientists at the Assistant Director level in the NSF, and, to the best of my knowledge, only one out of 26 Division and Office Directors in the five disciplinary directorates. To anyone knowledgeable about how scarce resources are allocated in organizations, these facts speak for themselves. Only social scientists can represent adequately the needs and opportunities of social scientists. And they can do that only if they participate in the highest levels of the organization, where allocations of funds are effectively made.

These observations are not a criticism of the abilities and efforts of the Foundation's staff. They are a criticism of an organization structure that prevents social science staff from being fully effective in its ~~adequacy~~ advocacy role. To correct this organizational distortion calls for the separation of the Biological, Behavioral and Social Science Directorate into its two natural parts, and the appointment of a new Assistant Director for the Behavioral and Social Sciences.

Secondary Education in the Social Sciences

Most talented young people who choose a career in science make that choice, at least tentatively, while still in secondary school. By that time, they have had opportunities for exposure to physics, chemistry, biology, and mathematics, and to the role of research in these fields. This exposure, where they have actually seen how research creates new knowledge, defines the meaning of "science" for them.

Few of these students have been exposed to the idea that the methods of science can be applied to the study of human individual and social behavior. Their first contact with this idea comes from college courses in the social sciences -- most often after they are already committed to majors in the physical or biological sciences. The social sciences are then reduced to trying to seduce to their fields able students who are already preparing for a different career.

The introduction into our secondary schools of more genuine social science courses that illustrate how the methods of science can be applied to human affairs is essential if these disciplines are to recruit the talent that their progress requires. The National Science Foundation's science education programs should include activities directed toward this goal.

Science Education

Physical and biological scientists have played the principal roles in the science education programs of the Foundation; social scientists a much smaller role. The concern here (as distinct from the point just made above) is not that these programs have been directed almost exclusively at improving instruction in physical and biological science. The concern is that learning is a psychological and social process whose organization and conduct need to be informed by social science knowledge. A great deal of relevant knowledge exists today, especially in cognitive science.

NSF Social Science Programs

The post-Sputnik curricular efforts in NSF were only partly successful. Many of their failings can be traced to the neglect of available knowledge about human learning processes, and the domination of the curriculum-design groups by subject-matter specialists who knew their disciplines very well but who did not have a thorough grounding in contemporary cognitive science.

We should not make that error again. Cognitive psychology has made great progress, and has even more to contribute today to the design of learning materials than it did two decades ago. The science education program needs scrutiny to determine whether social scientists and social science research findings are utilized in the program to the best advantage.

That is all I have to say, but, in addition, I should like to submit for the hearing record a thoughtful summary of the recommendations of the National Research Council report ("The Behavioral and Social Sciences: Achievements and Opportunities") as well as some graphs showing the trends in support for the behavioral and social sciences.

Implementing the National Academy of Sciences' Recommendations

for

Behavioral and Social Science Research

at the

National Science Foundation

Organizations supporting the recommendations:

American Anthropological Association · American Economic Association · American Educational Research Association · American Historical Association · American Political Science Association · American Psychological Association · American Psychological Society · American Sociological Association · American Statistical Association · Association of American Geographers · Association of American Law Schools · Consortium of Social Science Associations · Federation of Behavioral, Psychological and Cognitive Sciences · International Society for Developmental Psychobiology · Linguistic Society of America · National Academy of Neuropsychologists · Psychometric Society · Society for Computers in Psychology · Society for Psychophysiological Research

IMPLEMENTING THE NATIONAL ACADEMY OF SCIENCES' RECOMMENDATIONS for BEHAVIORAL AND SOCIAL SCIENCE RESEARCH at the NATIONAL SCIENCE FOUNDATION

The Behavioral and Social Sciences: Achievements and Opportunities, a 1988 report of the National Academy of Sciences (NAS), should prove an important Congressional resource in the development of science policy. It reflects the work of over 300 distinguished scientists who assessed the contributions of behavioral and social science in meeting national needs -- needs like increasing worker productivity, improving educational quality, and reducing crime and drug abuse. The report, the culmination of over five years of intensive work, maps a comprehensive blueprint for the federal government's future investment in behavioral and social science. The National Academy of Science concludes that an additional $240 million per year should be spent on behavioral and social science research government-wide; $60 million more at the National Science Foundation.

A striking finding of the report is a disturbing and severe imbalance -- indeed, a steady and significant decline -- in federal support for behavioral and social science, particularly in relation to other disciplines. Between FY 72 and FY 87, federal support for behavioral and social science declined by 25% in constant dollars; federal support for other science increased by 36%.

Equally disturbing is that NSF has made little or no attempt to address the important initiatives highlighted in the NAS report, a report which NSF funded. In fact, both the NSF FY 89 spending plan and the FY 90 budget proposal, rather than making social and behavioral science a higher priority as recommended by the report, contribute to the deepening void between the resources necessary and the resources provided to make critical advances.

It is vital that NSF provide national leadership to increase a federal commitment to behavioral and social science. NSF provides 25% of the federal support for psychological and social science research in colleges and universities and about 40% in the social sciences alone. Changes in the nature and level of NSF support would have a major effect in these areas.

What follows is a brief summary of proposals identified in the NAS report for the federal government's future investment in behavioral and social science; recommendations for NSF funding for these initiatives; and the justification for these investments.

RESEARCH FUNDING RESOURCES

Individual Investigator Research -- The major mechanism for enhancing research in behavioral and social science should continue to be individual investigator grants competitively awarded through peer review.

Proposed Additional Investment: $30 million annually

Justification:

- Enhanced investment in research grants is needed to sustain productive investments and to encourage investigation into such areas as cognition, international economic relations, organizational effectiveness, neuroscience, behavior change, reading and language acquisition, decision-making, geographic information systems, and political and social institutions.

- Findings from this research are applicable to advances in artificial intelligence, fighting crime, improving the U.S. trade position, more powerful designs of computers, more practical and innovative designs of robots, building a quality workforce, addressing homelessness, fighting AIDS, preserving the environment, and more efficient approaches to illiteracy.

- The social and behavioral sciences receive most of their funding from the NSF Directorate for Biological, Behavioral, and Social Sciences. But, while the title of the directorate implies parity among the three areas, it is not budget parity. In FY 87, the budget for behavioral and social research combined was about 25% of the $200 million budget for biological research.

- Here are a few facts. In FY 80, 6.1% of NSF's Research and Related Activities budget was allocated for behavioral and social science research; in FY 90, it is proposed to be only 4.1% -- a 33% decrease. Similarly, FY 89 will provide behavioral science programs with an increase of 3.6% over FY 88 levels, as compared to increases as high as 7.9% for other BBS programs.

- These are not isolated examples. They reflect a consistent trend toward progressively greater disparity between behavioral and social science and other areas, even though behavioral and social science is fundamental to solving our nation's problems.

SCIENTIFIC HUMAN RESOURCES

Predoctoral Support -- An effort must be made to attract more research- oriented students into graduate programs in the behavioral and social sciences and to upgrade the average level of research training in graduate schools. This can best be achieved by increased support for predoctoral fellowships and training grants.

Proposed Additional Investment: $9 million annually

Justification:

- The most serious problem of graduate departments in the behavioral and social sciences is the increasing difficulty of recruiting and retaining talented students.
- Between 1975 and 1985, federal support for graduate research assistants, fellows, and trainees decreased significantly. While this was true for all fields, the declines were steepest for the behavioral and social sciences -- fields that were much more dependent on federal support than other sciences.
- An additional 1,000 nonfederally funded graduate positions disappeared during the same years. The decline was notable in the most prominent departments; between 1975 and 1982 the total number of full-time graduate students receiving any type of federal support in the top quartile of behavioral and social sciences departments declined by 53%. In other sciences the comparable number increased by 15%.

SCIENTIFIC HUMAN RESOURCES (continued)

Postdoctoral Support -- An increase in postdoctoral support in the behavioral and social sciences should be divided among new training grants to institutions, individual fellowships at the junior level, and more advanced fellowships. The objective is to add 400 full-time doctoral level scientists to the numbers working at the frontiers of behavioral and social science research.

Proposed Additional Investment: $5 million annually

Justification:

- Postdoctoral training is becoming an increasingly important component in developing productive behavioral and social scientists. This is particularly true in the rapidly advancing interdisciplinary fields such as cognitive science, neuroscience, aging, linguistics, community studies, and artificial intelligence -- all of which require a behavioral science perspective.

- For the 5,850 new behavioral and social sciences PhDs in 1986, there were a mere 1,600 postdoctoral research positions (fellowships, associateships) and entry-level jobs devoted primarily to research and development, about 27 openings per 100 doctorates. This compares to 66 prime research openings per 100 new doctorates in the life sciences and 59 openings per 100 new doctorates in the physical and engineering sciences.

- New PhDs as well as those early in their careers need to have access to a range of postdoctoral research opportunities. Teaching loads of assistant professors in the behavioral and social sciences are often heavier than in other fields, and universities generally do not provide research funds or facilities for faculty in these sciences as routinely as they are provided for other fields. Generally lower salaries put financial pressure on new faculty to supplement their standard 9-month teaching base pay with summer teaching, or other employment -- infringing on time that could instead be devoted to research.

BEHAVIORAL AND SOCIAL SCIENCE EDUCATION

Pre-college and College Education -- An increase in support -- for textbook and curricula development, and teacher training for secondary schools and colleges -- aimed at introducing scientifically sound behavioral and social science at the secondary school and college levels will greatly advance the cause of an informed citizenry.

Proposed Additional Investment: $4 million annually

Justification:

- America is under siege by an attitude of indifference to science and sometimes even an anti-science public sentiment. This recent upsurge is to a large extent a function of three interrelated factors: science illiteracy, a failing science education system, and students allocating their time to other activities.

- The speed with which scientific advances are being made increases the distance between everyday knowledge and scientific knowledge. Science education efforts in secondary schools and colleges are inadequately preparing students for critical and analytical thinking, as well as with too narrow a view of science.

- Behavioral and social science disciplines emphasize those scientific literacy skills that span formal interpretation of scientific phenomena and informal interpretation of everyday phenomena. These include critical thinking about complex issues, statistical reasoning, comprehension of probability, and logical interpretation of research data. Unlike sciences such as chemistry, biology, geology, and astronomy, the behavioral and social sciences are able to convey these important principles in a context especially meaningful at the level of everyday experience.

- Behavioral and social science disciplines are also intrinsically popular with students. They draw more students relative to other disciplines, but opportunities to take pre-college courses in the behavioral and social sciences are not nearly as prevalent as opportunities to take pre-college courses in other disciplines.

- The pre-college behavioral and social science courses that are offered do not emphasize scientific methods of inquiry, the theoretical foundations of knowledge, nor do they provide basic lessons in research methods. Changing these courses would combat the anti-science trend by exposing a significant portion of the American population to systematic inquiry and explanation in the behavioral and social realm. Ignoring this opportunity means losing these students, as many will not be exposed to scientific courses in other disciplines.

TECHNOLOGICAL AND OTHER RESOURCES

Access to the Tools of Research -- Computers and other laboratory equipment are an integral part of behavioral and social science research. Adequate funding must be provided.

Proposed Additional Investment: $11 million annually

Justification:

- Because of a substantial erosion in the support for equipment in the last decade, there is a serious impediment to the rate of scientific progress in many behavioral and social research areas.
- Examples of equipment include: neuroimaging and other electronic devices to record brain activity during cognitive, language, emotion and motivation, motor, or perceptual tasks; audio devices for presenting sounds in studies of hearing and artificial speech recognition; parallel processing computers to design alternative systems for military, economic, and social needs; mini- and micro-computers and software for computer graphics, experiment control operations, data collection, and analysis in such areas as human learning and memory, geography, macro and micro econometrics, modeling of social and individual behavior, and teaching.

Skills Enhancement/Advanced Training -- Intensive short-duration advanced- training institutes would help inject new methods into the research community, develop new lines of research, increase the publishing of results, and bring researchers in diverse topical areas up-to-date about their own or closely related research areas.

Proposed Additional Investment: $4 million annually

Justification:

- Because of changes in the mode of funding, these activities largely have been discontinued. Now, special research funds are no longer available to institutions for this type of program; instead, proposals for such training institutes must compete directly with individual-investigator proposals. Review panels rarely even consider funding such training programs from their "individual researcher" funds.
- There are many examples of areas in which such institutes would be valuable: dissemination of innovations in statistics, measurement, and scaling to a wider body of researchers; development of geographic information specialists; and encouragement of theoretical linkages across disciplinary boundaries, such as between the physical and social sciences.

TECHNOLOGICAL AND OTHER RESOURCES (continued)

Travel Grants -- There is a need to facilitate communication and collaboration among investigators. An inexpensive and flexible approach is to bring researchers together for short durations (1 to 6 weeks) on a periodic basis.

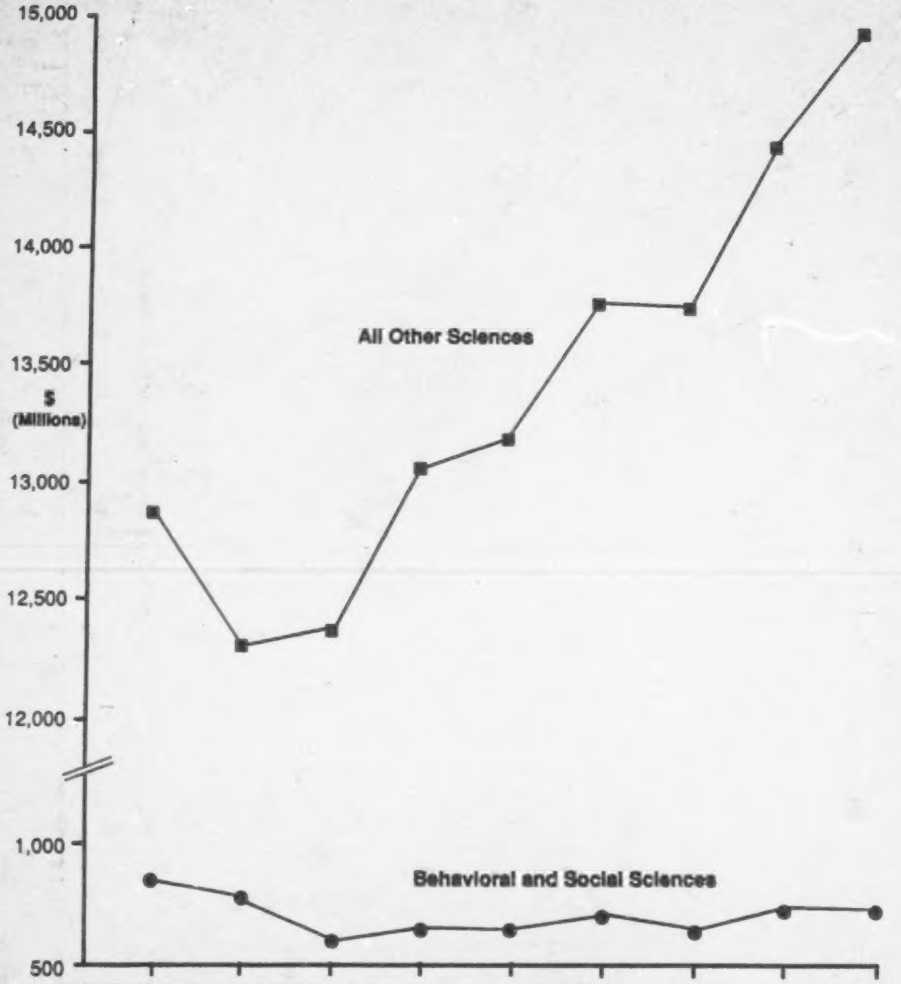
Proposed Additional Investment: $4 million annually

Justification:

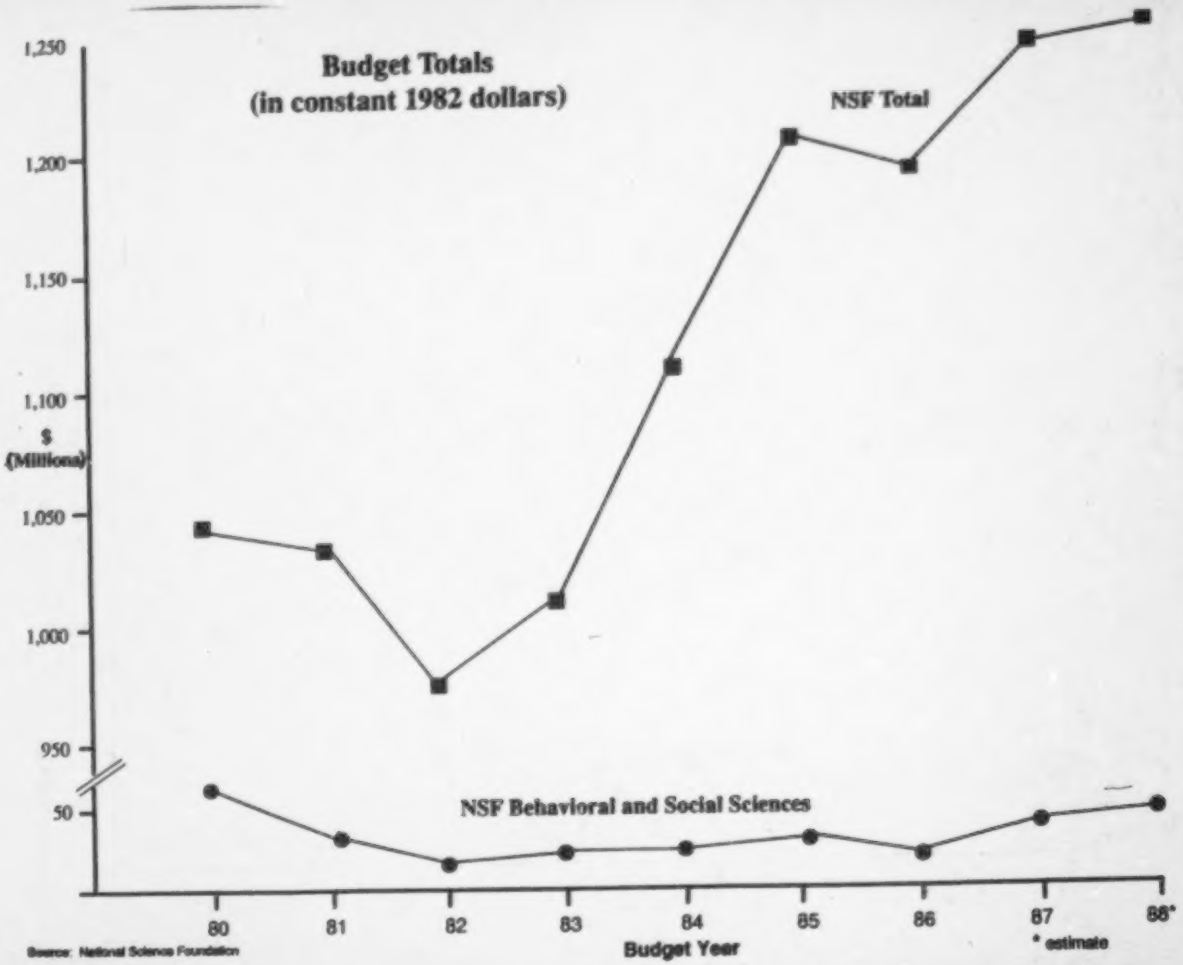
- Because behavioral and social science research is characterized by decentralization both within universities and geographically across the country, it is difficult to achieve a localized intellectual critical mass even within academic departments because of typically small numbers of faculty present with expertise in any given specialty.

- Grants for this type of activity have been drastically reduced in recent years, and when proposal budgets are scrutinized, travel costs are generally the first item to be cut.

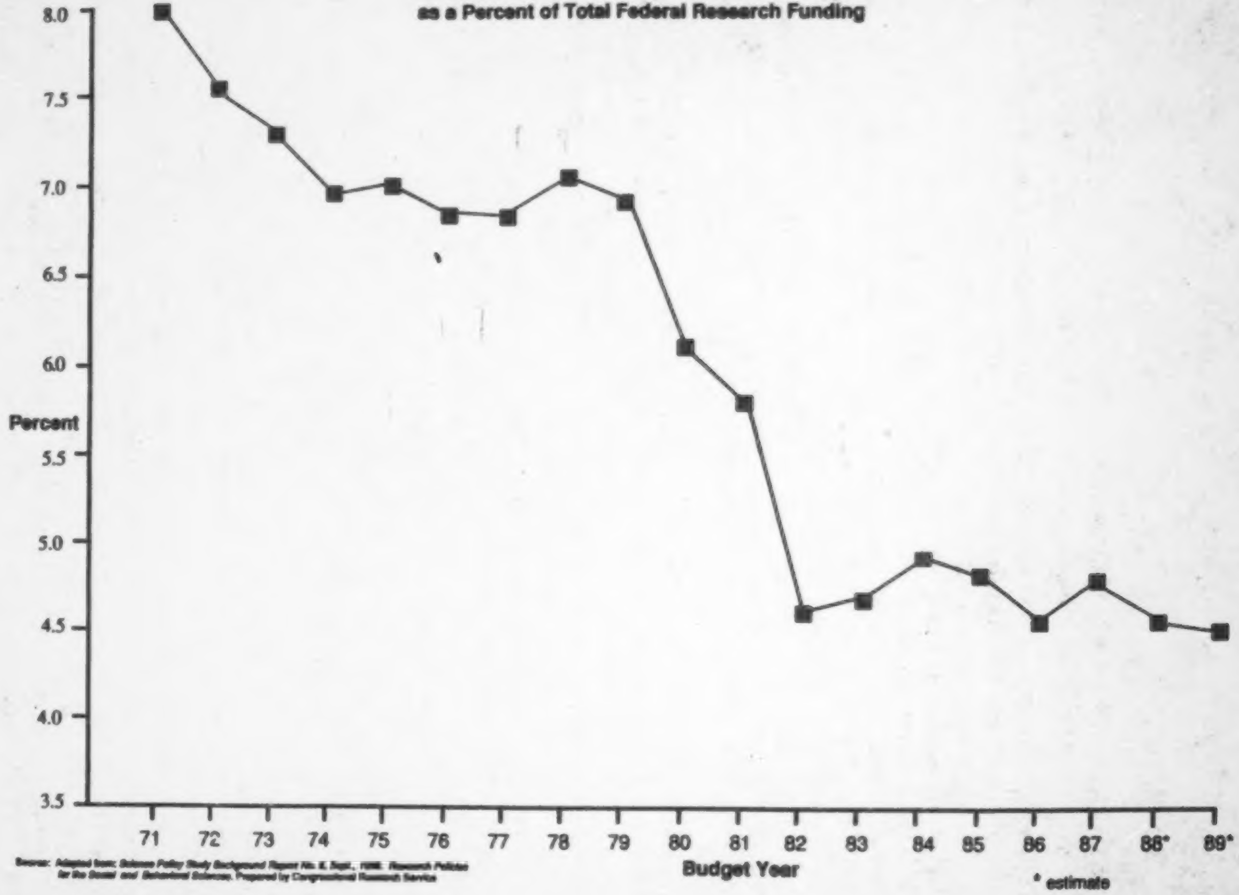
Federal Obligations for Total Research
(constant 1982 dollars)



Source: National Science Foundation



Source: National Science Foundation



Behavioral and Social Science Research Support as a Percent of Total Federal Research Funding

Source: Adapted from: Science Policy Study Background Report No. 6, Sept., 1986. Research Policies for the Social and Behavioral Sciences. Prepared by Congressional Research Service

Mr. **Walgren**. Thank you, Dr. Simon. We appreciate that testimony.

We will go on to the others and then come back for some discussion.

Mr. Schultze?

STATEMENT OF CHARLES L. SCHULTZE, DIRECTOR, ECONOMIC STUDIES PROGRAM, BROOKINGS INSTITUTION

Mr. **Schultze**. Thank you, Mr. Chairman and members of the subcommittee. Thanks for asking me to testify.

As an economist, I naturally emphasize what I know at least a little bit about, economic research.

If you turn to page 3 of my testimony—and I presume the testimony itself will go in the record and I will summarize—you will note some numbers that simply underline in a different way what Professor Simon has just said.

Despite budget stringency, from 1980 to 1988, the NSF budget in total, adjusted for inflation, went up by 20 percent. The budget for its Division of Social and Economic Science went down by 34 percent.

A decision has been made in the Nation—I think quite rightly—to reemphasize support for NSF, to push it up even faster, and the total NSF budget in the last several years, including the 1990 Reagan request, went up by 16 percent; the social and economic science budget, by 5 percent.

Now, the potential contribution of economic and social research to national well-being generally, and to policymakers specifically, may indeed have been overstated in the 1960s and 1970s. But there is no warrant for the current treatment of such research as reflected in the NSF budget.

My testimony gives a number of specific historical examples of ways in which economic research has improved our understanding of how the economy works and, through that understanding, has contributed, I think, to better economic policy. It also suggests some areas where further research, coupled with improved data collection, has a good promise of improving both understanding and policy.

In my oral summary, all I can do is highlight just a few of those examples. Let me start with a general proposition. Economic research, alone or in combination with other disciplines, can sometimes make a direct contribution to public policy by helping to design programs and evaluating their results. But mainly the results of economic research are valuable to society in an indirect way, to the extent that basic research provides greater insights into how our economy or segments of it operate and how families, workers, or business firms react to various kinds of economic stimuli.

Most successful research is of the type that adds its increment to our understanding about economic behavior or corrects some widely perceived misperceptions. There are few great discoveries or startling new inventions waiting in the wings, and I am not going to be able to give you any. And, indeed, you should, at least initially, be awfully skeptical when they are claimed. The gradual and persistent accumulation of useful knowledge is what we should expect from economic and social research.

Let me give you a few examples, if I might. One of the unappreciated facts about the American economy over the past 40 years is its far greater stability in terms of output, income, and employment, in comparison not only with the Great Depression but to the entire prior history of the country.

And so, on one standard measure of stability—the degree to which national output fluctuates around its long-term trend—the period since the Second World War has been more than twice as stable as the years between 1870 and 1914. Since World War II, there have been no annual declines in GNP as large as 2.5 percent. In the 70-year period to then, there were six declines larger than 2.5 percent.

The major credit for that difference arises from a much greater understanding among policymakers in the Executive Branch, the Congress, and the Federal Reserve, and among the public generally, about how monetary and fiscal policy ought to behave when the economy is threatened by recession. And that improved understanding was grounded on years of economic research.

We no longer try to raise taxes or cut government spending in recessions. And while Federal Reserve policy has been far from perfect, monetary instability in the postwar world has not played the major role it did in bringing on and worsening recession and depressions and exacerbating booms in the years between the Civil War and World War II.

Moreover, over the past 40 years, spurred by demands of researchers and the results of research on economic stability, the quantity, quality, and timeliness of the data which economic policymakers have at their disposal and the methods of analysis they have available to judge the current state of the economy, while far from perfect, have steadily improved.

Let me turn to another area, technology, R&D, and American productivity. Research by economists over the past three decades has, I think, greatly contributed to our understanding of the importance of technological advances and of industrial R&D to the growth of American productivity. Economic research in the 1970s and 1980s, for example, documented with increasing certainty the fact that business firms tend to earn, on average, a much higher return on their R&D than they do on other investments—25 percent versus 10 to 12 percent on the average for other investments.

Because the knowledge from successful R&D tends to disseminate quickly throughout the economy, it provides benefits to society over and above those reflected in higher profits and wages in the originating firm. And so a number of economic research studies have convincingly found that society gets, on average, an amazingly high rate of return—in the neighborhood of 50 percent—on the R&D carried on by American business, again, on the average.

Because individual R&D projects, however successful, on average are quite risky for the firms that undertake them, the unaided private market system tends to undertake too little R&D. And partly as a result of these economic research findings, the U.S. tax code now provides a tax credit for private R&D, and there appears to be wide support for making this credit a permanent part of the tax system.

Indeed, some very recent economic research has suggested ways of rewriting the conditions under which the credit is granted to make it more effective, to get more "R&D bang" for the tax buck. I understand that legislation has been introduced to accomplish that purpose.

Let me turn to a quite different subject, the nature and structure of welfare dependency, unemployment, and employee-employer relationships. The NSF and other government agencies have been supporting a good bit of research on improving the statistical techniques that enable social scientists to analyze the data on welfare and unemployment, and also employment.

Let me cite just one example of the findings of this kind of research which I think fits into your comment, Mr. Chairman, about the comment about the chairman of General Motors.

On a superficial look, the job tenure of American workers is rather short. In a working lifetime, the average worker will have held ten jobs. But more careful research with better data and statistical techniques has shown that this is misleading. Young workers move around a lot but eventually settle into long-term jobs. Thus, several studies have found that half of all the work done in America is performed in jobs where the job tenure is 15 years or longer, and if we confine our observations to adult male workers, it is 25 years or longer—half the work in America is done on jobs of that kind of tenure.

Among other implications of this research, the fact emerges that for the majority of firms and workers, long continuity of association and relationships of trust between particular firms and particular workers is a major aspect of our industry and an important contributor to productivity. It needs to be nurtured and improved. In that respect, the United States is different only in degree, not in kind, from the Japanese.

Let me turn almost at random to several other examples. Going back to productivity and looking ahead rather than backwards and talking about some research efforts in this area, starting in the early 1970s, the pace of American productivity growth slowed substantially from about 2.5 percent to about 1 percent a year. With productivity growth falling so sharply, the growth in American family incomes, real wages, and living standards necessarily also slowed to a crawl.

Careful economic research has done much to debunk a number of popular but fallacious explanations for that productivity slowdown. But its principal causes, unfortunately, still remain a mystery.

Economic research is now shifting from an examination of broad and macroeconomic causes to more detailed studies of the nuts and bolts, the microeconomic determinants of productivity growth at the firm and industry level. Some promising suggestions and leads are being explored, whose pursuit may ultimately provide useful information both for business managers and public policymakers.

Let me just tick off a few, again almost at random: Research is being conducted to determine what we can learn from specific examples about the relationship between productivity in the workplace, on the one hand, and the way in which workers are compensated, on the other—regular wages, bonuses, profit-sharing, ESOPs, and the like.

Recent research has shown that plants of some multi-national companies often have high productivity performance regardless of which country they are located in. Japanese auto companies in the United States are good examples, but they are not the only ones. These research findings suggest that the quality of management is a very critical factor in determining the pace of productivity growth.

Some researchers have come to the conclusion that American firms suffer because, on average, they do not know how to borrow or to imitate successful technological advances made in other countries. For three decades after the Second World War, the United States was the world's technological leader, and most new technology came from here. Now the source of new technological advances is much more diffuse throughout the world, but American firms have not changed their attitudes and have not become adept at copying from other countries.

Thus, in Japan, technological journals and research results from other countries are widely available in translation. But despite Japanese technological success, there is apparently little effort in the United States to translate or otherwise take advantage of Japanese research in technical journals. We need to learn how to borrow more.

Finally, but in a related vein, through research studies about the nature of R&D carried on by business firms, we know that the United States has concentrated on developing new products, while Japan has concentrated on producing new products more cheaply. One study found that commercial R&D in the United States is allocated about two-thirds to new products and one-third to improving production processes. In Japan, the proportions are reversed.

Thus, the United States leads the world in developing new specialized semiconductors, while the Japanese concentrate on ways to mass-produce semiconductors cheaply and hence are steadily increasing their market share in the semiconductor industry.

My only reason for inflicting on you all this highly selective recitation is to make the point that some very specific research has been getting under way which is not the traditional examination of the broad macrodeterminants of productivity but deals with what I said was the nuts and bolts and detailed underpinning of comparative productivity performance. A many-fold intensification of this kind of research is warranted.

To be slightly fanciful, if, as a result of such research, the rate of American productivity growth could ultimately be improved by only one-tenth of 1 percent a year for 5 years—one-tenth of 1 percent for 5 years—the annual addition to our national income and output would pay for the entire NSF budget 15 times over.

Mr. Chairman, I have only kind of picked and, at random, tried to give you some sense of the kinds of things that ultimately can be useful to society if we learn better not so much magic answers to anything, but how our economy behaves and how individuals and firms respond to economic stimuli.

I think it is terribly worthwhile. It does not generate anything immediately and quickly, and very often you cannot ever find it except with a lot of research at the end because it works its way into the very fabric of our understanding of our economy. But I think it is worthwhile.

Thank you, Mr. Chairman.

[The prepared statement of Mr. Schultze follows:]

Statement

of

Charles L. Schultze*
Brookings Institution

before the

Subcommittee on Science, Research and Technology

Committee on Science, Space, and Technology

U. S. House of Representatives

March 14, 1989

Mr. Chairman and Members of the Subcommittee:

Thank you for asking me to testify about the importance of behavioral and social science research and support of such research by the National Science Foundation. As an economist I naturally emphasize what I know at least something about -- economic research.

The Decline of Support for Economic and Social Research

If this hearing had been held twenty years ago, the environment would have been one of great support for and high expectations about the payoff from economic and social research. At the overall, or macroeconomic level, the U.S. economy had then just come through almost eight years of uninterrupted economic expansion and the press had given the President's economic advisers an important (and perhaps undeserved) share of the credit. In matters of social policy it was widely believed that economic and social research could provide specific answers about how to design efficient and effective government programs that would sharply ameliorate such social ills as poverty, poor housing, structural unemployment, and inequality of educational opportunities.

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*The author is Director of the Economic Studies Program at the Brookings Institution. The views set forth here are solely those of the author and do not necessarily represent the opinions of the trustees, officers or other staff members of the Brookings Institution.

Well, as we all know, that optimism about the ability of professional advice, backed by economic research, to give us uninterrupted prosperity and to find solutions to a host of specific social ills was far overdone. The economy in the 1970s and early 1980s went through a time of serious trouble, with three major recessions, two serious bouts of inflation, and an upward drift in unemployment. And our social problems turned out to be far more stubborn and less amenable to governmental actions than earlier believed. Not surprisingly, in reaction to the earlier excessive optimism, the pendulum swung to the other extreme. The reputation of economists and the credibility of economic advice took a steep fall, and the very real contributions that economic research could in fact make toward managing the economy and helping policymakers deal with specific economic and social problems became significantly undervalued.

One consequence of this general attitude showed up in the allocation for economic and social research in the budget of the National Science Foundation. The table below summarizes the changes in the overall budget for NSF, and in the tiny portion (1-1/2 percent) of that budget which goes to its Division of Social and Economic Science.

Change in Inflation-Adjusted Budget Authority for NSF and its Division of Social and Economic Science

(percent change)

	1980 to 1988	1988 to 1989	1989 to 1990 (request)
NSF, Total	+20	+6	+10
S.E.S. Division	-34	+1	+4

Despite the large budget deficits, the budget stringency and more recently the pressure for austerity exerted by the Gramm-Rudman law, the overall NSF budget, after adjustment for inflation, managed to grow over the past eight years, albeit quite modestly -- by some 2-1/4 percent a year or 19 percent altogether. But the inflation-adjusted budget for social and economic science fell precipitously, by 34 percent over those same years. More recently, in response to the belated recognition that a large increase in federal support for nondefense R&D was called for, given America's problems with low productivity growth and impaired competitiveness, the budgets for NSF have been stepped up sharply. But social and economic science shared virtually none of this increase for 1989, and comes in for only a small increase in the 1990 request.

While I agree that the potential contribution of economic and social research to national well-being generally, and to policymakers specifically, may have been overstated twenty years ago, there is no warrant for the current treatment of such research, as reflected in the NSF budget. In the remainder of this testimony I want to try to demonstrate, by way of a few specific historical examples, that past economic research has in fact improved our understanding of how the economy works, and through that understanding has contributed to better economic policy. Then I would like to suggest some areas where further research, coupled with improved data collection has a good promise of improving both understanding and policy.

First, a general proposition. Economic research, alone or in combination with other disciplines, can sometimes make a direct contribution to public policy by helping to design programs and evaluating their results. But mainly, the results of economic research are valuable to society in an indirect way, to the extent they provide greater insights into how our economy or segments of it operate and how families, workers, or business firms react to various economic stimuli. Most successful economic research is of the type that adds its increment to our understanding about economic behavior or corrects some widely perceived misperceptions. There are few great discoveries or startling "new inventions," waiting in the wings, and indeed we should, at least initially, be skeptical of when they are claimed. The gradual and persistent accumulation of useful knowledge is what we should expect from economic and social research.

The recent Report of the National Research Council, The Behavioral and Social Sciences: Achievements and Opportunities, contains an extensive review of the major directions that economic research has been taking in recent years. And I have benefitted greatly from it in preparing the testimony. But I know of no way to summarize briefly for you the past and potential future contributions of economic research and analysis. What I can do that may be useful is to provide specific examples in two categories: (1) some important historical contributions that economic research has made to the formulation of public policy; and (2) several ongoing research efforts which, especially if intensified, have some possibility of providing a better understanding of how our economy works, and in that way, of improving public policy. Given the limitations of both time and my own knowledge, I have been highly selective, and have necessarily had to neglect vast areas of economic research. Please do not take my list of examples as comprehensive or fully representative.

Some Historical Examples

Economic Stability. One of the unappreciated facts about the American economy over the past forty years is its far greater stability in terms of output, income, and employment in comparison not only to the Great Depression but to the entire prior history of the country. Thus, on one standard measure of stability -- the degree to which national output fluctuated around its long-term trend -- the period since the Second World War has been more than twice as stable as the years between 1870 and 1914.[1] In those early years the American economy spent

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[1] Some recent work by a young economic historian argues that the way in which we have reconstructed nineteenth century data exaggerates the economic volatility of the time; GNP did fluctuate more than it has recently, but the difference is smaller than hitherto reported. My reading of the subsequent controversy is that the reconstructed data do tell essentially the right message; the nineteenth century American economy was a good bit more volatile than the economy has been since World War II.

55 percent of the time expanding and 45 percent declining. In the period since World War II, on the other hand, the ratio of time spent in expansion to time in decline was 4 to 1. Since World War II there have been no annual declines in GNP as large as 2-1/2 percent. In the 70 years prior to then, there were six declines larger than 2-1/2 percent.

The major credit for that difference in behavior arises from a much greater understanding among policymakers in the Executive Branch, the Congress, and the Federal Reserve, and among the public generally about how monetary and fiscal policy ought to behave when the economy is threatened by recession. And that improved understanding was grounded on years of economic research. We no longer try to raise taxes or cut government spending in recession. And while Federal Reserve policy has been far from perfect, monetary instability has not played the major role it did in bringing on and worsening recessions and depressions and exacerbating booms in the years between the Civil War and World War II. Moreover, over the past forty years, spurred by the demands of researchers and the results of research on economic stability, the quantity, quality, and timeliness of the data which economic policymakers have at their disposal, and the methods of analysis they have available to judge the current state of the economy, while far from infallible, have steadily improved. A piece of evidence for this improvement has been the ability of the Federal Reserve to help keep the U.S. economy on an even keel for the past six years, despite unprecedented budget and trade deficits, huge swings in exchange rates, and a stock market crash second only to the Great Depression.

Technology, R&D, and American Productivity. Research by economists over the past three decades has greatly contributed to our understanding of the importance of technological advances to the growth of American productivity. The work of Nobel Prize winner Robert Solow in 1957, followed by the research of Edward Denison and others in the 1960s and 1970s revolutionized the then current thinking about the underlying sources of economic growth, and in particular stressed the very large and critical role payed by technological advance. Later work in the 1970s and 1980s documented, with increasing certainty the fact that business firms tend to earn on average, a much higher return on their R&D than they do on other investments (25 percent vs. 10-12 percent). Because the knowledge from successful R&D tends to disseminate quickly throughout the economy, it provides benefits to society over and above those reflected in higher profits and wages in the originating firm. Thus, a number of economic research studies have convincingly found that society gets, on average, an amazingly high rate of return, in the neighborhood of 50 percent, on the R&D carried on by American business. Because individual R&D projects are quite risky for the firms that undertake them, however, the unaided private market system tends to undertake too little R&D. Partly as a result of these research findings, the U.S. tax code now provides a tax credit for private R&D, and there appears to be wide support for making this credit a permanent part of the tax system. Indeed, some very recent economic research has suggested ways of rewriting the conditions under which the credit is granted to make it more effective -- to get more "R&D" bang for the tax buck" -- and I understand that legislation has been introduced to accomplish that purpose.

The Nature and Structure of Welfare Dependency, Unemployment, and Employment

The NSF and other government agencies have recently been supporting a good bit of research on improving the statistical techniques that enable social scientists to analyze the data on welfare and unemployment, particularly as it relates to the flow of people into and out of welfare and unemployment status, and the duration of their stay on the rolls.

Before 1980, social scientists and policymakers disagreed about the nature of welfare dependency in the United States. Some policymakers and economists claimed that welfare dependency was typically quite brief. According to this view, single mothers with children received welfare benefits for relatively short spells after losing a job or a working male partner, but quickly went off the rolls when a new job or marriage partner was found. Other analysts claimed the opposite: welfare dependency could last for years or decades, as single mothers became addicted to receiving public assistance.

Research over the past decade -- based on the new statistical methods -- has shown that both these interpretations are correct to some degree. The great majority of women receiving welfare at some point in their lives will receive benefits only briefly -- less than two years. In no sense will they become addicted to public assistance. On the other hand, a majority of women receiving welfare at a given point in time are in the middle of a very long spell of dependency -- lasting five, ten, or even twenty years, with only brief periods of time off the rolls. These women account for the bulk of money spent on public assistance benefits.

This set of findings has been directly reflected in recent welfare reform efforts. The AFDC program is now recognized to serve two kinds of populations -- one that receives benefits as a temporary source of aid during brief spells of misfortune, and the other that receives assistance for very long periods. Different kinds of reform are appropriate for these two populations. The public is far more concerned about preventing long spells of dependency than it is about providing assistance that will last only a few months or one or two years.

A somewhat similar set of findings has merged from detailed studies of flows into and out of unemployment. At any moment of time most of the unemployed in the United States have been unemployed for a relatively short period of time -- for example, in January almost half of unemployed Americans had been without a job for less than five weeks, and only a tenth had been unemployed for six months or longer. (Our experience is much different from that of European countries where typically half of the unemployed have been out of work for six months or longer.) Despite the high percentage of American unemployed found by the survey to be out of work for only short periods of time, careful research has shown that most of the total weeks of unemployment suffered by American workers are accounted for by those who have been unemployed for long periods of time, and that the probability of a person finding a job within the next month actually declines the longer the person has been unemployed.

Finally, the same sort of pattern emerges when we examine carefully the flows into and out of employment. On a superficial look the job tenure of American workers is rather short -- in a working lifetime the average worker will have held ten jobs. But more careful research, with better data, has shown that this is misleading: young workers move around a lot, but eventually settle into long-term jobs. Thus, several studies have found that half of all the work done in America is performed in jobs where the job tenure is fifteen years or longer, and if we confine our observations to adult male workers, it is twenty-five years or longer. Among other implications of this research the fact emerges that for the majority of firms and workers long continuity of association and relationships of trust between particular firms and particular workers is a major aspect of our industry and an important contributor to productivity. It needs to be nurtured and improved. In that respect the United States is different only in degree, not in kind, from Japan.

Social Experiments. Over the past twenty years Congress has funded a number of "social experiments" under which alternative public program designs were tested in practice. Very careful economic research was necessary both to design and evaluate these experiments. From them, and especially from a series of tests on alternative designs of welfare programs, we have learned a great deal about how low income people respond in terms of work effort and other economic behavior to changes in the level of welfare benefits and earning opportunities.

Evaluating the benefits and costs of many social programs requires very sophisticated economic and social research. Take, for example, the case of a particular federal training program. To evaluate such a program it is not sufficient simply to observe the earnings and employment experience of trainees before and after training, since earnings and employment opportunities may have also changed for those who had not been participants in the training program. Hence, at a minimum it is necessary to compare the earnings and employment record of trainees with a comparison group chosen to be similar in all important respects with the trainees. But there may be a "selection bias" -- for example, those who choose to enter the training program may be precisely those with more ambition and better potential work habits, who could have been expected to do better anyway. The only alternative then is to evaluate the program through a social experiment in which people are randomly assigned to training and to a control group. But social experiments are costly to the government, time consuming, and have other disadvantages. Recently, however, some sophisticated economic research has been done to develop statistical criteria, which, relying on background data about the trainees and the control group, can determine with some degree of confidence whether or not selection bias is likely to be small enough so the usual, and less costly, evaluation techniques can be used. By applying these criteria themselves or through contractors, the policy evaluation staffs of executive agencies, the CBO, and the GAO can more confidently design and rely upon evaluation studies, and also identify the situations when such studies cannot be relied upon.

The Usefulness of Research When the "Obvious" Answer is the Wrong Answer

Sometimes in economic life what appears to be an obvious cause and effect relationship turns out to be misleading. Here is where careful economic research and analysis can be most useful. Tracing out the major economic effects of trade negotiations is a good example of this situation. It seems obvious that when a country like Japan is running a large trade surplus with the United States, negotiating restraints on specific Japanese exports to the United States (e.g., automobiles) or using our bargaining leverage to overcome barriers to U.S. imports of, say, telecommunications equipment would reduce the Japanese surplus. In fact, however, that is not likely to be the long-run effect of such negotiations. If we restrict Japanese imports into the United States of commodity X, then the Japanese Japanese trade surplus may indeed, for a time, shrink. But with a smaller trade surplus there would be a scarcity of dollars available to Japanese investors who want to buy U.S. securities to take advantage of our high interest rates. And so, the dollar will be bid up, and the yen will depreciate. With a lower yen, other Japanese exports to the United States will rise, and their overall trade surplus will tend to return to its earlier level. To be sure, they will sell less of commodity X to us (at a higher price), but more of Y and Z. A similar turn of events would occur as we negotiated a greater opening of Japanese markets to, say, our exports of telecommunications equipment. Such exports would rise,and that might indeed be desirable, but others would fall. In short, trade negotiations principally affect the composition of our international trade, but the overall size of our trade deficit is mainly determined by macroeconomic developments here and abroad, especially the levels of national saving and budget deficits in various countries and our interest rates relative to those elsewhere in the world.

Knowledge of these results of economic analysis does not itself tell us what sort of trade policies to follow, but it surely should help us make better decisions and avoid costly mistakes.

Some Research Efforts with Potential Future Payoffs to the Nation

Productivity Growth. Starting in the early 1970s the pace of American productivity growth slowed substantially, from about 2-1/2 to about 1 percent a year. Necessarily with productivity growth falling so sharply the growth in American family income, real wages, and living standards of families also slowed to a crawl. Careful economic research has done much to debunk a number of popular, but fallacious, explanations of the productivity slowdown. But its principal causes still remain a mystery. Economic research is now shifting from an examination of broad macroeconomic causes to more detailed studies of the microeconomic determinants of productivity at the firm and industry level. Some promising suggestions and leads are being explored, whose pursuit may ultimately provide useful information both for business managers and public policymakers.

- Research is being conducted to determine what we can learn from specific examples about the relationship between productivity in the workplace and the way in which workers are paid -- regular wages, bonuses, profit-sharing, ESOPs, etc.

- Recent research has shown that the plants of some multinational companies often have high productivity performance regardless of which country they are located in. Japanese auto companies in the United States are good examples, but not the only ones. These research findings suggest that the quality of management is a very critical factor in determining the pace of productivity growth.
- Some researchers have come to the conclusion that American firms suffer because, on average, they do not know how to imitate successful technological advances made in other countries. For three decades after the second World War the United States was the world's technological leader, and most new technology came from America. Now the source of new technological advances is much more diffused throughout the world, but American firms have not changed their attitudes and have not become adept at copying from other countries. Thus, in Japan technological journals and research results from other countries are widely available in translation. But despite Japanese technological success, there is apparently little effort in the United States to translate or otherwise take advantage of Japanese research and technical journals.
- In a related vein, through research studies about the nature of R&D carried on by business firms, we know that

the United States has concentrated on developing new products, while Japan has concentrated on producing new products more cheaply. One study found that commercial R&D in the United States is allocated about 2/3rds to new products and 1/3rd to improving production processes; in Japan the proportions are reversed. Thus, the United States leads the world in developing new specialized semi-conductors, while the Japanese concentrate on ways to mass produce semi-conductors cheaply, and hence are steadily increasing their market share in the semi-conductor industry.

- A recent piece of research, using detailed data from Japanese, American, and European auto companies has documented that U.S. and European carmakers use more labor and require longer lead times to develop new auto models than do their Japanese counterparts. Moreover, the study pinpoints the specific differences in organizational approaches and managerial techniques that appeared to produce that result.

My only reason for inflicting on you this highly selective recitation, is to make the point that some very specific research is getting underway which is not the traditional examination of the broad determinants of productivity but deals with the nuts and bolts and detailed underpinning of comparative productivity performance. A manyfold intensification of this kind of research is warranted and has the prospect of providing important insights into the nature of American productivity problems and suggestions for improvement. And here even seemingly small improvements can yield large payoffs. To be slightly fanciful, if as a result of such research the rate of American productivity growth could ultimately be improved by only one-tenth of 1 percent a year for five years, the annual addition to our national income and output would pay for the entire NSF budget fifteen times over.

The Noninflationary Level of Unemployment. Right now, with unemployment still a bit over 5 percent of the labor force, we are beginning to see some signs of an upturn in wage and price inflation -- not a sharp upturn, but a beginning. Much economic research has been directed toward understanding better the way labor markets work, and an important part of that research seeks to understand better why it is that the level of unemployment at which inflation starts to rise is so high. In the process of that research we have begun to learn much more about the subtleties and complexities of the relationships between employers and employees with respect to wages, job tenure, and productivity performance. As I mentioned earlier we are also learning more about the nature and composition of the flows into and out of unemployment and about the process of job search. We need more information and analysis about the extent to which the provision of better information about job availability and worker characteristics might produce more efficient matches between unemployed people and vacant jobs, and thereby lower the unemployment rate at which inflation starts to rise.

Here again, the potential payoff to improving our knowledge could be quite high. If the nation could lower the noninflationary level of unemployment by only 0.1 of one percent, the payoff in terms of higher national income and output would be sufficient to cover the entire annual budget for NSF three times over.

Explaining the U.S. Trade Deficit

Several important studies have recently tested the ability of large scale econometric models of the international economy -- in Japan, Europe, and the United States -- to predict how international trade flows will develop given the internal developments in each country. One major finding of this research was that most of the models did reasonably well and gave similar results in tracing out the course of the U.S. trade deficit *if* they were fed data on what had happened to exchange rates. But they did a very poor job and differed from each other substantially when they were not given the exchange rates, but had to *predict* them on the basis of what else happened internally in each country.

The moral of this story is that economic research has done a reasonably decent, though far from perfect, job of enabling us to understand and predict how international events and exchange rates affect international trade flows. But we have a long way to go in being able to predict how international developments and policies in various countries affect exchange rates. Given the large and steadily growing importance of international trade developments for the prosperity of modern nations and the crucial role of exchange rates, it is essential I think that we intensify research in this area.

Data Needs

For many years economic research relied heavily on two kinds of data: (1) times series data which are periodic (annual, quarterly, monthly, etc.) averages or totals of important economic variables -- GNP, interest rates, steel production, sales by industry, etc.; and (2) cross section or "snapshot" data which provide detailed information across a sample of individuals or firms at a moment in time -- e.g., decennial census data, periodic surveys of consumers, the monthly Current Population Survey, etc. Increasingly over the past two decades, however, we have come to recognize and rely upon a third, and, unfortunately quite expensive type of data collection -- longitudinal data files. These files, based on surveys or government records, provide various kinds of data on a continuous sample of individuals or families, so that we can track developments over time -- they represent, if you will, a continuing series of snapshots of the same sample of people, firms, etc. Thus we can trace how firms or individuals, grouped by various characteristics, respond over a number of years to various kinds of economic developments.

One of the major recommendations of the National Research Council Report on the Behavioral and Social Sciences was for the NSF to devote substantial additional resources to the collection of such longitudinal files, with data from workers, families, and business firms.

A major body of highly important research depends upon the availability of such longitudinal data. Such research topics include: the causes and consequences of changes in the distribution of jobs and income across industry, occupation, educational and socio-economic groups; the hiring, layoff, promotion, and wage-setting practices of business firms; and the response of firms to changes in their domestic and international environment.

If, as another example, we had possessed more extensive longitudinal data on the financial and other performances of individual firms, we would be able to trace, much better than we now can, the subsequent fortunes of those firms which have been involved in mergers and acquistions, and that ability would have made a substantial contribution to the current public policy debate.

I strongly endorse the National Research Council's recommendation that substantial additional resources be devoted to the collection and improvement of such data files, including in some cases the use of sample data from government files, appropriately reviewed and sanitized to preserve the confidentiality of individual responses.

CURRICULUM VITAE

CHARLES L. SCHULTZE

CURRENT POSITION	Director, Economic Studies Program, 1987-, Economics
PREVIOUS POSITIONS	Senior Fellow, 1981-87, 1968-1977 Lee Kuan Yew Distinguished Visitor, National University of Singapore, November 1985 Distinguished Visiting Professor of Research, Graduate School of Business, Stanford University, 1982-1983 Chairman, Council of Economic Advisers, 1977-1980 Director, U.S. Bureau of the Budget, 1965-1967 Asst. Director, U.S. Bureau of the Budget, 1962-1964 Asst. Prof. and Professor of Economics, Univ. of Maryland, 1961-87 Lecturer and Assoc. Prof. of Economics, Indiana Univ., 1959-61 Staff Member, Council of Economic Advisers, 1952, 1954-1958 FIELD OF SPECIALIZATION - ECONOMICS
EDUCATION	Ph.D., Economics, University of Maryland, 1960 M.A., Economics, Georgetown University, 1950 B.A., Economics, Georgetown University, 1948
HONORS and AWARDS	President, American Economic Association, 1984
MEMBERSHIPS	Life Trustee, The Urban Institute Member, American Economic Association Fellow, National Association of Business Economists Member, National Academy of Public Administration Member, International Advisory Board, AB Volvo
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PUBLICATIONS

Books:

American Living Standards: Threats and Challenges, (ed. with Robert E. Litan and Robert Z. Lawrence), Brookings, 1988

Barriers to European Growth: A Transatlantic View, (ed. with Robert Z. Lawrence), Brookings, 1987

Other Times, Other Places, Okun Memorial Lectures, Brookings, 1986

Co-author, Economic Choices 1987, (with Aaron, Galper, Pechman, Perry, Rivlin and Schultze), Brookings, 1986

The Public Use of Private Interest, Godkin Lectures, Brookings, 1977

Higher Oil Prices and the World Economy: The Adjustment Problem, (ed. with Edward Fried), Brookings, 1975

Co-author, Pollution, Prices, and Public Policy, (with Allen Kneese), Brookings, 1975

The Distribution of Farm Subsidies, 1971

Co-author, Setting National Priorities (four volumes), (with Fried, Rivlin and Teeters), Brookings, 1970, 1971, 1972, and 1973

The Politics and Economics of Public Spending, 1968

National Income Analysis, Prentice-Hall, (Third Edition), 1964

Recent Inflation in the United States, 1959

Articles:

"Microeconomic Efficiency and Nominal Wage Stickiness," American Economic Review, March 1985

"Cross-Country and Cross-Temporal Differences in Inflation Responsiveness," American Economic Review, May 1984

"Industrial Policy: A Dissent," The Brookings Review, Fall 1983

"Long-Term Budget Strategies," Setting National Priorities: The 1983 Budget, Brookings, 1982

"Some Macro Foundations for Micro Theory," Brookings Papers on Economic Activity, 2:1981

"Falling Profits, Rising Profit Margins, and the Full Employment Profit Rate," Brookings Papers on Economic Activity, 2:1975

"Prices and Wages," (with J. Tyron), The Brookings Quarterly Econometric Model of the United States, 1965

"Short-Run Movements of Income Shares," 1964

Mr. **Walgren**. Thank you very much, Mr. Schultze. We appreciate that testimony.

Mr. Gorham?

STATEMENT OF WILLIAM GORHAM, PRESIDENT, THE URBAN INSTITUTE

Mr. **Gorham**. Mr. Chairman, I, too, appreciate the privilege and the honor of appearing before this committee, and also especially the pleasure of appearing with Charlie Schultze and Herb Simon.

I will focus my remarks on the research developed by NSF grant-supported social scientists that has dramatically increased the power of other social scientists and policy analysts to understand the problems of our society and to assess and predict the effects of policies aimed at changing those problems.

To echo Charlie's last statement, there is little doubt that the budgetary cost savings and the program benefits that stem from these advances alone have already paid many times over for the entire social science, probably the NSF budget.

The work of that translation of basic social science into policy is done by policy analysts. Policy analysts have become the intellectual bridge between the discipline-oriented research of university centers and departments, on the one hand, and policy officials on the other.

Public policy analysis serves the public interest in three ways: It tends to assess and project the conditions of society and its problems; it evaluates existing efforts to tackle these problems. I might point out that Charlie Schultze and I had the pleasure, in about 1966 or 1967, of inventing something called the 1 percent set-aside, which was that 1 percent of all program monies appropriated would be made available for evaluation purposes. That created an industry. [Laughter.]

The third thing that policy analysis does, the hardest thing, is that it appraises the relative merits of alternative future policies.

Since 1953, which is the beginning of my own career in public policy research, the application of systematic analysis to public decisions has mushroomed. The growth has not been uniform. During the first few years of the Reagan Administration, interest in analytical information dipped sharply.

However, it is fair to say that a taste for reliable and increasingly analytical information is now well established. Administrators and legislators have come to expect and rely upon an amount and sophistication of information that would have been difficult to imagine in the sixties.

Policy research organizations, by and large, do not conduct basic social science or methodological research; they are its users. They organize their efforts around policy problems and issues, and they aim their work at public decisionmakers or, through the media, at the public. Thus, they are the link between basic research and the ultimate beneficiaries of that research.

I would like to cite three very important contributions of NSF's program to research that bear directly on policy, one in each of the three categories of policy analysis I cited.

The first is on assessing problems. Usually a problem is studied after the public has observed its prevalence first-hand—homelessness, for example—or after the media have brought it to light, as has been the case in the epidemic growth in crack and crack-connected crime.

Once in a while, a significant problem is brought to light by the research community itself, as was the case in the growth of the number of Americans who have no health insurance at all.

In the fall of 1988, my own Institute completed a study of homelessness. We sought to answer the obvious questions which were not answered: How many are there? Has the number been changing? Who are they? How long have they been homeless? What resources are available to them? What are their other troubles? Because of the currency of this particular issue, I have appended some charts (that we did from one of the committees to this statement) and the article presenting the results.

This study was based on field surveys. Finding and interviewing homeless persons is challenging. Designing such a survey so that it can be used to represent the universe of the American homeless would have been impossible but for the pioneering analytical work carried out under NSF social science grants. Because of this seminal work, researchers are now able to have reasonable confidence in the results of their surveys and the analyses of the survey data.

In the second category, the evaluation of public programs, I would like to say that only if one has not tried can one hold the view that finding out what works is easy. It is difficult because a policy intervention—the introduction of a program or a change in a program level in significance, be it a service or a financial inducement on behalf of some objective (for example, tax relief in exchange for private investment in problem) ridden urban areas, the enterprise zone proposals—is not the only variable affecting the objectives. Some of the other variables are measurable; those are sometimes manageable. The most difficult problems are posed by the ones that are unmeasurable and unobservable.

Selection bias is a particularly persuasive form of the general problem of unobservable variables. In all instances of evaluating the effectiveness of a policy, the analysts confront the problem of bias due to unobservable factors, and they have got to try to adjust for it.

One example: For almost any kind of insurance, people differ with respect to the risks that they represent. In many cases, the true risks cannot be observed or can be easily concealed. Health insurance coverage for AIDS victims represents an extreme case of such bias.

Another form of selection bias is selection by a program manager, sometimes called "creaming". In this case, the person allocating the resource tries to channel it to those most likely to succeed. This, too, leads to the measurement difficulty of selection bias, since the effects of the program on someone's likelihood to succeed will be overestimated to the extent that this highly selected group would have succeeded anyway.

Selection bias was the main reason why several very expensive social experiments were sponsored by the Federal Government in the period from the late sixties through the early eighties, to test important possible changes in income transfers, housing, housing vouchers, and health insurance programs. I believe something in the order of $275 million was spent for those social experiments.

The social experiments were characterized by a random assignment technique which eradicated selection bias by assigning persons from the same pool to either experimental, the programs, or control groups. The two groups by definition shared the same characteristics on the average except for their program status.

In the last several years, statistical techniques have been developed, in part with NSF support, to correct for selection bias. These have made it possible to evaluate government programs with existing program data, at a fraction of the cost of social experiments.

Yet another aspect of evaluation research that has benefited from theoretical NSF support has been process or implementation analysis. In order to make sound recommendations for improving government programs, it is necessary to understand organizations, including behaviors within them, incentives and disincentives to change. I will not describe this; Dr. Simon would be in a much better position than I to.

The program implementation studies draw very heavily on the organizational theory and behavior research that has been supported by NSF.

The final category is the appraising of future policy. What one wants to know when one is selecting a policy is how it will perform relative to other possible policies. That includes doing nothing about a problem. This prediction is the business end of policy analysis, the aspect of most relevance to public decisionmaking. And it is the hardest.

While, for the most part, policy impact prediction is still more art than science, major advances have been made. Charlie referred to some in econometric modeling; I would like to refer to another in microsimulation. You will have to excuse the expression, "dynamic microsimulation modeling." That is what I would like to talk about for a moment.

We have the privilege and pride of having had the most serious effort in this field started at the Urban Institute in 1969, a year after we were founded. It was under the initial leadership of Guy Orcutt, who was its pioneer, and it has come to be exceptionally useful in assessing policy choices, especially those that have a very long term of unfolding, such as changes in the social security system.

The current version of the model that we developed, called DYNASIM, simulates individual and family behavior in order to produce a realistic forecast of the economic and demographic characteristics of the families in the United States for some future year.

The model starts with a representative sample of individuals and families. These families and persons within families evolve from year to year, experiencing divorces, marriages, birth, dying, working, being employed, and so forth, all within the computer. Each year's forecast population can be analyzed and represents a synthetic sample of the U.S. population in some future year.

During its history, DYNASIM has been used for a variety of policy applications. Many of these studies were initiated by congressional requirement. Examples are on page 9 of my statement of ones that we have been involved in.

Estimation of models that are capable of simulating behavior require a longitudinal data base, which is a data base similar to the one that Dr. Simon referred to when he spoke of the 300 adolescent mothers. One such data base, the Panel Study on Income Dynamics, the PSID, has played a crucial role in the development of DYNASIM. It would not have been possible without it. Indeed, in the second year of that longitudinal model, they were running out of money, and the Urban Institute contributed $100,000 to its continuation. The PSID was also funded by NSF.

The advent of the PSID facilitated the initial development of DYNASIM, as I mentioned. The PSID has been used to estimate models capable of predicting events not only on the basis of current individual characteristics but also on the basis of these individuals' histories. What we have in the current PSID as of this year is a 21-year continuous history of approximately—I guess it started with—9,000 families.

That concludes my examples. As with Charlie, I circulated among my staff and got virtually 30. I selected these three as the largest and most significant.

Finally, let me say that the grist for the policy analyst's mill is the stuff of social scientists. Politicians and administrators, when they think about it at all, are put off by the pace of learning in social science and the difficulty of tracking its contribution. They have even less patience with the guarded ways in which social scientists or policy analysts hedge their findings.

That is just a case of the where-you-stand-depends-on-where-you-sit homily. It is exactly right for social scientists and policy analysts to reveal only the amount of truth they can verify. That is what the science demands. If they did not behave that way, they would deprive our society of the essential values of their domain—objectivity, reliability, and credibility.

This essential rigidity limits their role because policy *choices* almost always involve considerations, often overriding ones, that go beyond the limits of the legitimate terrain of the social scientists or the capacity of the tools at their disposal.

The policy world, in contrast, is driven by the necessity to decide. That necessity requires that they go with what they have by way of enlightenment when the decisions should and must be made. Both perspectives are essential, and I am certainly talking to the believers when I address it to this group.

It was a pleasure to make my statement to you.

[The prepared statement of Mr. Gorham follows:]

SOME USES OF NATIONAL SCIENCE FOUNDATION-SPONSORED RESEARCH

Statement of

William Gorham

President, The Urban Institute

before the

Subcommittee on Science, Research, and Technology

Committee on Science, Space, and Technology

U.S. House of Representatives

Washington, D.C.

March 14, 1989

The opinions expressed herein are the author's alone and should not be attributed to The Urban Institute, its officers, trustees, or funders.

Introduction

I am William Gorham. I am the President of The Urban Institute. I appreciate the opportunity to appear before the Committee together with my distinguished colleagues, Charley Schulze and Herb Simon.

Because I am convinced of the merit of bringing organized intelligence to bear on the problems of our society, it is a privilege to speak about NSF- supported research which I know from personal experience has been of great benefit in this respect.

I will focus my remarks on a particular set of analytical techniques and data bases developed by grant-supported social scientists that have dramatically increased the power of other social scientists and policy analysts to understand social and economic phenomena, and to analyze and predict the effects of policies aimed at changing them. While I have not done the arithmetic, I would be surprised if the budgetary cost savings and the program benefits that stem from these advances alone have not already paid many times over for the entire Behavioral and Social Sciences program.

Policy analysis has become the intellectual bridge between the discipline-oriented research of university centers and departments, on the one hand, and policy officials, on the other. Public policy analysis is concerned with and serves the public interest by: (1) assessing and projecting the state of society's condition and problems; (2) evaluating existing public (and sometimes private) efforts to tackle such problems; and (3)appraising the relative merits of alternative future strategies and policies.

In the years since 1953 (the beginning of my own career in public policy research), the application of systematic analysis to the public decision process has mushroomed. This growth has paralleled comparable developments in the private sector. The evolution has not been uniform among levels of government. The federal government has generally been ahead of the states, which have been ahead of the cities. Nor has momentum been uninterrupted--during the first few years of the Reagan Administration interest in analytical information dipped sharply. However, it is fair to say that a taste for reliable and increasingly analytical information is now well established. Administrators and legislators have come to expect and rely upon an amount and sophistication of information that would have seemed difficult to imagine in the late sixties.

Institutions have been created and others redirected to deliver this information. At Congress's disposal are: the Congressional Budget Office, the General Accounting Office, and the Congressional Research Service of the Library of Congress. At the disposal of the executive branch, in addition to the traditional heavy-duty statistical agencies--the Bureau of Labor Statistics and the Census Bureau--are a number of departmental analytical organizations--e.g., the Office of the Assistant Secretary for Planning and Evaluation (ASPE) in the Department of Health and Human Services--have been added. These statistical and analytical agencies numerate and illuminate different aspects of our society and prepare or contract in the private sector for evaluative and other analytical studies.

In response to this demand outside government, several major public policy research organizations--the Brookings Institution, the American Enterprise Institute, the Rand Corporation, The Urban Institute--maintain staffs of social scientists and policy experts who sift, search, and analyze primary data (some like Rand and The Urban Institute produce new data) for illumination and insights on myriad subjects of policy consequence. Virtually all this flow of information becomes grist for the decision mill. A number of smaller institutions and commercial research organizations do the same thing on narrower fronts, such as manpower training, criminal justice, child development, income transfers, public taxation, health programs, and more.

These policy research organizations by and large do not conduct basic social science or methodological research. They are its users. They organize their efforts around policy problems and issues, and aim their work at public decisionmakers or, through the media, at the public. They are, thus, the link between basic research and the ultimate beneficiaries of that research.

Apart from six years in a policy position in the federal government--DOD and HHS--my career has been in this sort of institution and thus I view the contributions of NSF's Behavioral and Social Sciences program from that vantage point.

I will cite three very important contributions of NSF's program to research that bears directly on policy--one in each of the three categories of policy analysis I mentioned earlier.

Examples of the Use of NSF-Supported Research in Policy Analysis

(1) Assessing Social and Economic Problems

Usually a problem is studied after the public has observed its prevalence firsthand--homelessness, for example--or after the media have brought it to light, as in the case of the epidemic growth in crack use and crack-connected crime. Once in a while a significant problem is revealed by the research of a policy institute, as was the case with the growth in the number of Americans with no health insurance at all.

Whatever the initial impetus, when there is a demand to go beyond the journalistic and the anecdotal to a scientific appraisal, policy institutes are now there to meet that demand. Their role is to develop to the extent possible--and make public--a balanced view of the nature, origins, extent, and consequences of such problems. Such elaboration is a reasonable prerequisite to determining whether or not public action (or private action) is warranted.

In the fall of 1988 the Institute completed a study of the homeless. We sought to answer a number of obvious questions. How many are there? Has the number been changing? Who are they? How long have they been homeless? What resources are available to them? What are their other troubles? Because of the currency of the issue I have appended to this statement some charts and an article that present the results.

This study was based on field surveys. Finding and interviewing homeless persons is challenging. Designing such a survey so that it can be used to represent the universe of the American homeless would have been impossible but for the pioneering analytical work carried out under an NSF Behavioral and Social Sciences grant. Because of this seminal work, researchers are now able to have reasonable confidence in the results of their surveys and the analyses that use survey data.

Comparable studies have been conducted by the Urban Institute on the medically uninsured, teenage mothers, very elderly women, youthful crack dealers, to mention a few. All these efforts owe a major debt to this and related methodological research.

Bringing intellectual horsepower to the task of understanding our society's problems has benefits in and of itself through: dispelling socially dysfunctional myths about the problems; placing them in perspective, thus adding light rather than heat to public and policy discussions and debates; undermining really bad ideas about what to do about the problems; and, sometimes, suggesting good ways to address them. Twenty-five years ago it was rare to assess the social illnesses with care before prescribing the medicine, and when it was done because the analytical tool chest was slim--little confidence could be vested in the result.

(2) Evaluating Public Programs

Only if one has not tried can one hold the view that finding out "what works"--i.e., evaluating the performance of a government (or any other, for that matter) program--is easy. It is difficult because a "policy intervention" or "treatment"--be it a service or a financial inducement (transfers or tax breaks) on behalf of some objective (e.g., tax relief in exchange for private investment in problem-ridden urban areas)--is not the only variable affecting the objective. Some of these other variables are measurable. The most difficult problems are posed by the ones that are unmeasurable.

Selection bias is a particularly pervasive form of the general problem of unobservable variables. In all instances of evaluating the effectiveness of a policy, except evaluations that are based on a design that randomly assigns a pool of individuals to treatment or nontreatment status--impossible in many program contexts--the analyst confronts the problem of bias due to unobservable factors, and must try to adjust for it. Selection bias can take several forms, and also goes under several names. One form is self-selection, sometimes called adverse selection or moral hazard. An example: For almost any kind of insurance, people differ with respect to the risk they represent. In many cases the "true" risk cannot be observed (or can be easily concealed). Health insurance coverage for AIDS victims represents an extreme case.

There are other, more subtle forms of self-selection. For example, the wage distribution. It is likely that at any given time the average potential wages of those not working, were they to find a job, are less than the average actual wages of those already working. In the abstract, this implies that a policy that increased the number of people working (but did not change their skill level, for example) might reduce average wages. Similarly, if a new training program were offered on a voluntary basis, members of the target population who volunteered for the program would most likely be more motivated for success than those who did not volunteer. In each example, the "true" risk, the "true" productivity, or the "true" level of motivation is unobserved and a potential source of bias in estimating the effects a given program would have on groups other than the particular group currently participating.

Another form of selection bias is selection by a program manager, sometimes called "creaming." In this case, the person allocating a resource tries to channel it to those most likely to succeed. This too leads to the measurement difficulties of selection bias, since the effects of the program on someone's likelihood to succeed will be overestimated to the extent that this highly selected group would have succeeded anyway.

Selection bias was the main reason why several very expensive social experiments were sponsored by the federal government in the period of the late 1960s through the early 1980s, to test important possible changes in income transfer, housing, and health insurance programs. The social experiments were characterized by a random assignment technique which eradicated selection bias by assigning persons from the same pool to either experimental (program) or control (non-program) status. The two groups by definition shared the same characteristics on average except for program status.

In the last several years statistical techniques have been developed, in part with NSF support, to correct for selection bias. These have made *it possible to evaluate government* programs with existing program data--at a fraction of the cost of the social experiments. While there remains some controversy about how well these techniques make up for the absence of the much more expensive random assignment design, even if the proponents of the statistical corrections are half right in their claims, the cost-effectiveness of the accomplishment is huge.

Yet another aspect of evaluation research that has benefited from theoretical NSF-supported work has been process, or implementation analysis. In order to make recommendations for improving programs, it is necessary to understand organizations, including behaviors within them and bureaucratic incentives and disincentives to change. Program implementation studies draw heavily on organizational theory and behavior research, once again supported in part by NSF-Behavioral and Social Science. One such study that has just begun is an Urban Institute evaluation of the Washington State Family Independence Program.

(3) Appraising Future Policy Alternatives

What one wants to know when one is selecting a policy is how it will perform relative to other possible policies (including doing nothing). This prediction is the business end of policy analysis--the aspect of most relevance to public decision-making. While, for the most part, policy impact prediction is still more art than science, major advances have been made in econometric modeling that project the performance of the economy under a variety of changes in economic policy. These have become very sophisticated and they are generally helpful for macroeconomic planning.

Another development, dynamic microsimulation modeling, begun in 1969 at the Urban Institute under the initial leadership of Guy Orcutt, has come to be exceptionally useful in assessing policy choices that have a very long impact period, such as changes in the social security system.

The current version of that model, called DYNASIM, the Dynamic Simulation of Income Model, simulates individual and family behavior on an annual basis in order to produce a realistic forecast of the economic and demographic characteristics of the families in the United States for some future year. The model starts with a representative sample of individuals and families (typically from the Current Population Survey), and simulation units (families and persons within families) evolve from year to year, experiencing divorces and marriages, birth, dying, working, being unemployed, and so forth. Each year's forecasted population can be analyzed as a synthetic sample of the U.S. representative of some future year.

During its history DYNASIM has been used for a variety of policy applications that require long-range forecasts of economic and demographic histories such as social security or pension programs. Many of these studies were initiated by congressional requirements that the long-range consequences of policies in the retirement and aging area be evaluated. Study examples include:

1. Analysis of alternative social security benefit structures as part of a study to suggest solutions to the "double indexing" program (HEW, 1976).

2. Analysis of ways that the social security system could be restructured to accommodate the changing roles of men and women (HEW, 1979).

3. Estimation of the long-range effect of changing the Age Discrimination in Employment Act (ADEA) to increase the legal mandatory requirement age to 70 (Department of Labor, 1981).

4. Estimation of the social costs of teenage child bearing (NICHD, 1982).

5. Estimation of the long-range effects of options to revise the rules governing private pension plans (HHS, 1984).

6. Estimation of the long-range effects of the 1983 Social Security Amendments (CDP. 1983).

7. Analyses of earnings sharing alternatives to the current social security benefit structure (Ford Foundation, 1984, and CBO, 1986).

8. Estimation of the long-range effects of reducing pension vesting to five years. as included in the 1986 Tax Act, and analysis of a bill proposed to require pension coverage for more part-time workers (Rockefeller, 1988).

Most recently DYNASIM has been developed to examine issues related to long-term care for older Americans. The Urban Institute is completing a study, for example, that estimates the demand for long-term health and social services to the year 2030 under alternative assumptions about mortality and health (AOA, 1989). The DYNASIM technology will soon provide a basis for accurately aging Current Population surveys for shorter-range forecasts and for simulating behavioral responses to changes in tax and transfer programs.

Estimation of models that are capable of simulating behavior require a longitudinal data base. One such data base, the Panel Study on Income Dynamics (PSID), has played a crucial role in the development of DYNASIM. The PSID was also funded in part by the NSF-BSS program. The advent of the PSID facilitated the initial development of the DYNASIM model in a very key way. This was the first time that a longitudinal survey was available to analyze a wide range of behavior. All of the DYNASIM labor market submodels rely on the PSID. These include a simulation of labor force participation, hours of work, unemployment, and work disabilities. The PSID has been used to estimate models capable of predicting these events not only on the basis of current individual characteristics, but also long-range histories of these events. This methodology significantly improves the accuracy of long-range forecasts of demographic and economic events.

Finally, a less sophisticated but very widely used computer simulation model called TRIM, used primarily to estimate costs and caseloads (or, the size of the affected populations) in various tax and transfer programs, has recently been made more accurate and reliable, thanks to new and increasingly powerful statistical and data-analytic methods developed with support from NSF.

Concluding Remarks

The grist for the policy analyst's mill is the stuff of social science. Politicians and administrators when they think about it at all are put off by the pace of learning of the social scientists; they have even less patience with the guarded way in which social scientists or policy analysts hedge their findings. That's just another case of the where-you-stand-depends-on-where-you-sit homily. It is exactly right for social scientists and policy analysts to reveal only the amount of truth they can verify; that is what "science" demands. If they didn't behave that way they would deprive our society of the essential values of their domain--objectivity, reliability, and thus credibility. This essential rigidity limits their role and that of their works because policy choices almost always have considerations--often overriding ones--that go beyond the limits of the legitimate terrain of the social scientists or the capacity of the tools at their disposal. The policy world, in contrast, is driven by the necessity to decide. That necessity requires that they go with what they have by way of enlightenment. I think we can be happy about their differences.

* * *

I would like to end by emphasizing again the powerful potential for improving public decisions that longitudinal data sets offer. These data sets have dramatically changed the ability of social scientists and policy analysts to contribute understanding, insight, and occasional guidance to a wide range of momentous decisions. But we are only at the beginning of potential. In my judgment, if we sustain the current level of investment (and probably make selective additional investments) the rewards in terms of more effective and efficient public policy will repay us and our heirs many, many times.

A-1.

THE HOMELESS:

THE FIRST
NATIONAL
STUDY

Study Objectives

- Assess Impact of Law
- Describe Eating Patterns
- Describe Other Characteristics
- Describe Operations of Soup Kitchens and Shelters

A-3.

Samples We Have

- 381 Soup Kitchens and Shelters
- 1704 Homeless Adults Who Use Soup Kitchens or Shelters
- 142 Homeless Adults Who Do Not Use Soup Kitchens and Shelters

A-4.

The Homeless

- o How Many?
- o Who Are They?
- o Are They Hungry?

A-5.

How Many Are Homeless?
March 1987

Service-Using Homeless Adults in Large U.S. Cities	110,000	**195,000**	275,000
All Homeless Adults and Children in Large U.S. Cities	230,000	**330,000**	470,000
All Homeless Adults and Children in The U.S.	400,000	**570,000**	800,000

A-6.

- Homelessness Has Increased Since 1983
  - 1983 HUD Study: 250,000 - 350,000
  - Our 1987 Estimate: Around 600,000
- Much Less than Advocate Estimates of About 3 Million

A-7.

Who Are the Homeless?

- o Demographic Characteristics
- o Length of Homelessness and Joblessness
- o Financial Resources
- o Troubles

What Proportion are Families?

- 10% of homeless service-using adults have one or more children with them.

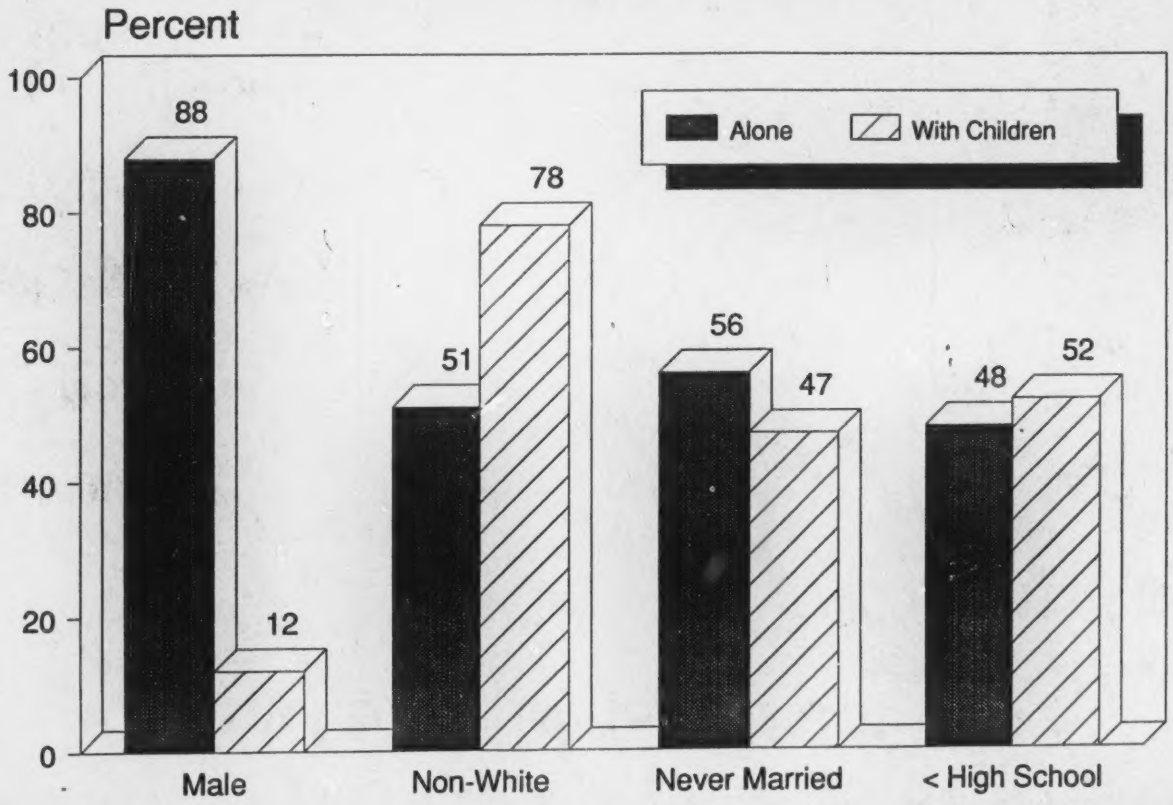
- Of all service-using homeless people:

  15% are children

  8% are adults accompanying these children

A-9.

Demographic Data (2)



A-10.

How Long Homeless/Jobless?

	Alone	With Child(ren)
Homeless		
3 months or less	19%	39%
12 months or less	51%	73%
4 years or more	21%	6%
Without Steady Job		
3 months or less	9%	11%
12 months or less	39%	38%
4 years or more	33%	33%

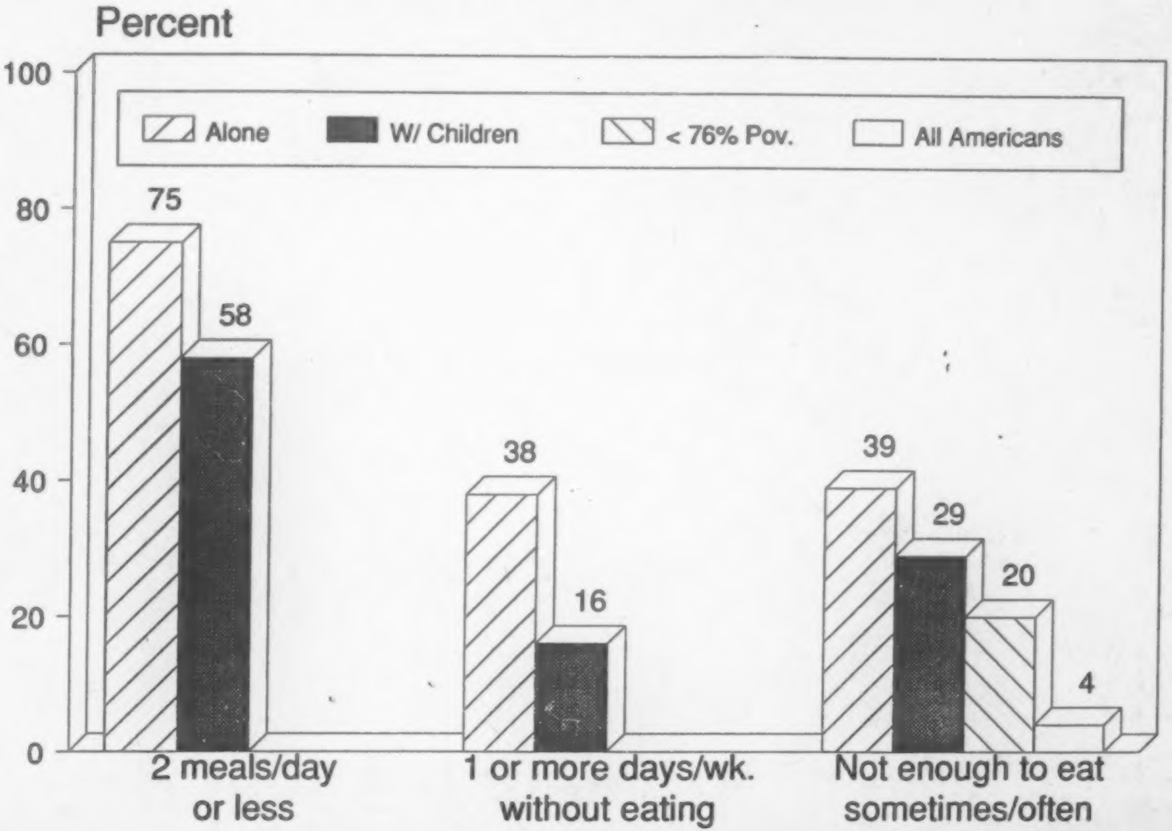
Financial Resources

	Alone	With Child(ren)
Cash Last Month		
Mean	$146	$301
Median	$ 64	$300
Cash Last Month from		
Working	25%	23%
AFDC	1%	33%
General Assistance	10%	33%
No Cash Last Month	18%	6%
Food Stamps	15%	50%

Personal Troubles

	Alone	With Child(ren)
Mental Hospitalization	20%	11%
Chemical Dependency Inpatient Treatment	35	12
Jail for 5+ Days	56	18
State/Federal Prison	26	2
None of Above	29	76
Any I	29	12
Any 2	22	6
Three or All Four	20	6

Are They Hungry?



A-14.

Policy Framework

- o Emergency Issues
- o Transitional Issues
- o Prevention

HUNGER AND THE HOMELESS:

POOR DIETS AND DAYS WITHOUT FOOD

A-15.

The plight of America's homeless is increasingly visible in the streets, train stations, and welfare hotels across the country. No good estimates exist of how many people are homeless in the United States, but the evidence around us suggests their numbers may be increasing. Public concern has focused on the most visible problem of the homeless — lack of shelter. Less attention is typically given to other aspects of their lives.

Do they go hungry? Are they malnourished? Are they homeless for short or long periods? Can they cope? Or do they have physical, mental, or behavioral problems that prevent them from making a different kind of life?

To date, nothing substantial has been known about whether the homeless get enough to eat or the right nutrients. Local studies can tell us something about other characteristics of homeless persons in the localities studied, but no nationally representative study has been done that can support generalizations about the homeless.

Survey Provides First National Picture of Homeless

This information gap is now closing. In-person interviews with the first nationally representative sample of homeless persons who use shelters and soup kitchens — and the first study ever to collect detailed information on what, where, and how much the homeless eat — now provide important answers to questions about hunger and malnourishment among the homeless. The interview data, collected and analyzed by Institute researchers Martha Burt and Barbara Cohen with assistance from nutritionist Nancy Chapman, also confirm local evidence about other characteristics of the homeless and strongly suggest a need to reevaluate the focus of programs serving this group.

On the good side, the survey reveals that while there are families among the homeless who use shelters and soup kitchens, these families represent only a small percentage of that population. Moreover, in almost all respects homeless families are less destitute than are their single homeless counterparts.

On the distressing side, the homeless who use shelters and soup kitchens suffer from crippling conditions beyond and more extensive than lack of shelter including chronic mental illness, chemical dependency, and long-term unemployment. Those who do not use these services are even more likely to have these conditions. Finally, the homeless are disproportionately black and Hispanic, more so than are the poor generally, raising the possibility that at least in the nation's larger cities the homeless form yet another layer of the underclass.

Programs that pour money primarily into the improvement of the physical plants of emergency shelters leave unaddressed the multiple and long-term needs of those served and thus do little to foster self-sufficiency. Yet, according to Burt and Cohen, changing the focus of such programs will be difficult. It is easier to garner public support to house the homeless in emergency shelters than it is to raise sympathy and resources to treat the long-term poverty or permanent disability that can force people into homelessness.

As part of a larger study by Burt and Cohen on the homeless population and their sources of food and shelter, a nationally representative sample of about 1,700 homeless people who use soup kitchens or shelters

Most homeless people who frequent soup kitchens, shelters, or both, do not eat three meals a day. Thirty-six percent reported that they go one day or more per week without eating anything.

Homeless people suffer from crippling conditions beyond and more extensive than lack of shelter, including chronic mental illness, chemical dependency, and long-term unemployment.

was randomly selected in 20 of the nation's cities with population of 100,000 or more. For comparison, 142 persons who do not use these services were interviewed in sites where the homeless congregate—parks, bus or train stations, street corners or alleys, and culverts and other parts of the highway system.

In interpreting the findings of the survey it is important to keep in mind that the statistically representative information is about the homeless who *do use* soup kitchens and shelters. The patterns for this group are, therefore, described first.

Hunger and Malnutrition Widespread

Most of the homeless people who frequent soup kitchens, shelters, or both, do not eat three meals a day. The average number of meals eaten a day, according to respondents, is slightly less than two. More than one-third reported eating one meal a day or less.

Homeless people also go whole days without food. Thirty-six percent reported that they go one day or more *per week* without eating anything. About one in four said they go two days or more without eating more than once a month; one in six said they go two days or more without eating as often as once a week.

Not only do the homeless who use soup kitchens and shelters eat relatively infrequently, their diets also lack essential foods. Calculations based on descriptions of what homeless people said they ate the previous day, for example, reveal that 65 percent had not consumed any milk or milk products during that day; 43 percent had eaten no fruits or vegetables; 30 percent had eaten no grain products; and 20 percent had eaten no meat or other protein sources. More than one in three reported that they sometimes or often do not get enough to eat, compared with one in twenty-five for the United States as a whole and one in five for those in extreme poverty (with incomes at three-quarters of the official poverty line or below).

Homeless Plagued by Multiple Problems

A range of characteristics indicates that the homeless are indeed an extremely disadvantaged group in the population, with both economic and noneconomic problems. These findings confirm information available from many local studies.

Economic Characteristics. Service-using respondents report very little cash income. The average income per person for the 30 days preceding the interview was $137.00. During this same 30-day period 17 percent reported no cash income. The service-using homeless have typically also been without a job for a considerable period of time—nearly two-thirds for more than one year and one-third for more than four years.

Physical and Mental Health. The homeless who use meal and shelter services tend to be in relatively poor physical and mental health. A majority (56 percent) reported at least one health problem, including 15 percent with joint problems, 15 percent with high blood pressure, and 10 percent with problems walking. Thirty-eight percent said their health was fair or poor, compared with 10 percent of the general population ages eighteen to sixty-four.

Mental health problems are prevalent. Almost 20 out of 100 reported a history of mental hospitalization. A similar proportion reported having tried to commit suicide—versus 3 out of 100 for the general population and 7 out of 100 for persons ever diagnosed as suffering from a major psychiatric illness. Finally, on a scale developed by the National Institute of Mental Health to measure current depression and demoralization, 43 percent had sufficiently high psychological distress to indicate the need for immediate treatment.

Institutionalization. Institutionalization experiences are prevalent. One-third have been patients in a detoxification or alcohol-drug treatment center. Half have spent more than 3 to 4 days in a county jail. One-quarter have served sentences in state or federal prisons. And nearly one-fifth have been institutionalized in three or all four types of institutions assessed (mental hospital, detoxification or chemical dependency center, county jail, state or federal prison).

Nonservice Users More In Need

Are the homeless who do not use shelters or soup kitchens different from those who do? Some have argued that these persons did not use services from choice—that somehow they were more independent, less in need, than the ones who sought at least some support.

It is no longer possible to use that argument. Even though the sample

A-17.

of nonservice-using homeless was small and not representative in a strict statistical sense, it is a national sample and the picture it paints is clear. A whole variety of comparisons made possible by the survey indicates that the homeless who do not use services are even more in need than those who do.

The homeless who do not use services reported being homeless longer, having been without a steady job longer, and having made less use of public benefits.

They reported being less healthy and having more mental problems. They also eat less, and less frequently. The homeless who do not use services also have poorer eating patterns than other homeless on every measure of dietary intake. They rely much more heavily on trash and handouts as sources of food. They average only slightly over one meal per day, and they are much more likely to go one or more days in a week without eating.

Finally, they are less likely to report getting enough to eat, and quite unlikely to get what they want to eat. More nonusers than users describe the quality of their diet as fair or poor; nonusers are less likely to have eaten foods in the five essential food groups.

Homeless Families Cope Better

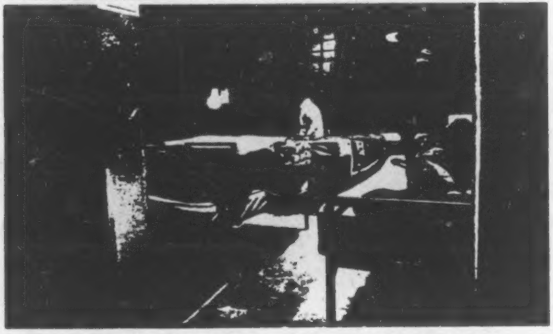
Three-quarters of the homeless who use soup kitchens and shelters are single persons who are by themselves. The remaining 23 percent are in families—8 percent of them adults, 15 percent the children who are with them. (This says nothing about how many biological children homeless persons have. The survey did not collect that information). It is also noteworthy that although there are undoubtedly families among the homeless who do not use services, there was not a single one among the group in The Urban Institute's nonservice-using sample. The survey did not interview the children in homeless families or ask the adults questions about the children who were with them. But information on the adults in the families can tell us quite a bit about the probable environment of the children.

The vast majority of adults with children are women. Compared to homeless adults who are alone, they are more likely to be nonwhite and currently married, and they have been homeless on average for much shorter periods of time.

Adults in homeless families who use shelters or soup kitchens are just as unlikely as singles to have worked recently, but are more likely to be current recipients of welfare and they receive more cash income — usually from welfare.

They also eat somewhat better, are less likely to have gone for whole days without food, and are more likely to report their diet as satisfactory. Even homeless adults in families, however, have a relatively poor diet; not much more than one-third have diets that contain all five essential food groups. Their physical and mental health is better, and they are much less likely to have been in a mental hospital, jail, or prison.

On one important dimension, however, homeless adults with children are no better off than their counterparts who are alone. Their scores on the scale of depression and demoralization are just as high — an indication that being homeless is an extremely difficult circumstance to deal with irrespective of one's general mental or psychological health.



The vast majority of homeless people who use soup kitchens and shelters are single adults. Only twenty-three percent are in families — eight percent of them are adults, and fifteen percent are the children with them.

Programs That Provide More Than Shelter Needed

The homeless are not a homogenous group. They are not homeless by choice. Shelter is by no means their only need, although it is clearly their most pressing and visible one.

According to Burt and Cohen, it is now time to develop public support for programs that do more than give the homeless a temporary roof — programs that distinguish among the homeless to meet their different long-term needs. Two groups of homeless in particular stand out: those who will never be able to support themselves, such as the chronically disabled; and those who suffer from serious economic deprivations, such as the long-term unemployed or welfare-dependent, but who are not otherwise disabled. The former require a source of income, housing assistance, and minimum case management to insure stability. The latter have a strong need for programs that foster self-sufficiency. They often have few or no job skills and poor education. Their needs beyond housing are similar to those of other long-term unemployed. They need higher benefit levels (to enable them to stay on welfare but not be homeless) and access to job training and placement programs.

For further information see "Feeding the Homeless: Does the Prepared Meals Provision Help?" prepared for the Department of Agriculture by Martha Burt and Barbara Cohen, with the assistance of Nancy Chapman, September 1988, available from the Institute's Publications Office for $22.00.

Mr. WALGREN. Thank you very much, Mr. Gorham. We appreciate that, and perhaps it should be filed under the category of forewarned is forearmed. Is that where that dynamic modeling will lead us? It is like Scrooge's Christmas future. We get a good look at what might be coming down the road, and maybe we might act more wisely in advance.

Mr. GORHAM. Precisely.

Mr. WALGREN. The Chair would like to recognize the gentleman from New York for a brief opening statement.

Mr. BOEHLERT. Thank you, Mr. Chairman.

I apologize for my delinquency, the late arrival of my plane this morning.

Mr. Chairman, this morning's proceedings remind me a little of those hearings on poverty that were held in the sixties. The attitude then was one of amazement that, in this affluent society, such deprivation could exist unnoticed and unattended. That sense of poverty amidst plenty is clearly present in the testimony to be presented to us this morning. We have already heard some of it. And the feeling has a foundation in fact.

At a time when NSF has been growing, albeit at a rate far below what this committee would like, the social sciences have been unable to regain their pre-Reagan funding levels. The astronomical sciences have withered under budgets that are anything but astronomical, and the Antarctic has continued its sad descent from pristine terrain to what seems more like the world's coldest superfund site.

Admirably, NSF has developed a plan to improve health and safety in the Antarctic, but it may be insufficient, and at any rate, the other two discrepancies remain. These issues merit further exploration with Erich Bloch at Thursday's hearings.

NSF is not at a budget level that can support all worthy research or research areas. Priorities must be set. This morning's testimony should provoke some questions about whether precisely the proper balance has been struck among NSF's many disciplines.

Thank you, Mr. Chairman.

Mr. WALGREN. Thank you, Mr. Boehlert.

Let me start off and then turn to other members.

You have really presented us good examples of the value and certainly direct testimony of the fact that the social and behavioral sciences have not been supported at previous levels and in fact do not seem to be participating in the rebuilding and the growth in NSF budgets as are other areas.

I guess I would like to ask in the shortest form why that is true. What is the problem? What kinds of resistances are we running up against? I want to see if I can get any candid comments from all of you on that question. Why aren't we, as they say? Can I start with Dr. Simon?

Dr. SIMON. I think I am not revealing any secrets if I say that there still is not a universal belief that the study of human behavior can be carried on with the same objectivity that the study of atoms or the study of beetles can be carried on, and I think that skepticism underlies part of the difficulty. That skepticism is found, not only in the lay public, but is found in the scientific community itself.

And, as I suggested in my testimony and in the annex to my testimony, it is reflected in the organization of the NSF itself. The people who can make the best case for the social sciences are social scientists. They have to speak to an understanding audience and a receptive audience, an audience that is willing to entertain the possibility that this kind of objective research is possible and pays off. There have not been very many voices at the top levels of the NSF who can make that case from their own understanding, their own knowledge, their own conviction.

It seems to me that the problem is going to persist in one way or another until there are such voices, and in particular, I think serious consideration is needed of the possibility of dividing the present Biological Behavior and Social Science Directorate into its two natural parts to make certain that there will be at least one assistant director for the behavioral and social sciences who speaks for those fields and who will be a central participant in the higher level budget decisions of the agency.

Mr. WALGREN. Mr. Schultze?

Mr. SCHULTZE. I fully subscribe to that. Let me add several speculations, at least.

Hard scientists tend to look down on soft scientists as second-rate citizens because the results of their discipline are less certain, less immediately and obviously connected to tangible consequences. I mean, the average citizen can read about some Nobel Prize winner having found a neutrino or a boson, and he doesn't know what the heck a neutrino or a boson is, but it sounds awfully important, and he is fairly sure from the history of nuclear science that some day that is going to lead to some major breakthroughs.

On the other hand, he tends to think of economists, for example, as on the one hand; on the other hand, you lay seven of them together and they will point in eight different directions, and so on. [Laughter.]

It is much less tangible; it is much less certain; it produces results for the good of society, if you want, much more indirectly. There are not many—there are a few—results of economic research that you could point to and say, here was research A and, by gosh, here is consequence B. You could do it indirectly. There is tremendous indirect influence in terms of understanding the behavior of our economy better, and as I indicated, the proof of the pudding is in the eating, and it is not by sheer chance that the U.S. economy has performed so much better in the last 40 years than it did in the prior 100 years.

But that connection is very, very remote and indirect. So the tendency of the hard scientists who dominate NSF to look down on the soft scientists because of the nature of their disciplines, and the tendency of the public to deprecate the softness and the uncertainty in the science, and finally, the difficulty of finding the connection between cause and effect in the social sciences all contribute to this.

Finally, I have to say that social science was probably overrated for a while in the late sixties. We had 8 years of continued economic expansion without interruption, and economists began to take more credit than they should have. There was a general view around in the days of the Great Society program that if you did a piece of social research, you could design programs that worked. We are finding that that was not quite as easy and quite as obvious, so there was a reflection, a reaction to this, I have to say.

Now, I think it has gone far too much the other way, and all those four things, I think, contributed to the problems we have.

Mr. WALGREN. Mr. Gorham?

Mr. GORHAM. I subscribe to everything that has been said before me. I would elaborate just for a moment on Herb Simon's representation in the highest NSF councils by social scientists.

Basically, when you talk about the products or the benefits to society of science versus social science, hard science, you are talking about incommensurables; you are talking about things that have no way of being compared. They depend on the values. They are political decisions. Therefore, you must have political power at the table. That should be very easy for Congress to understand, that if you need political power, you have to be sitting at the table in those decisions.

At the NSF, allocative decisions, if there are not at the first instant when the proposals are being made, if there are not sitting at those tables people who understand, represent, and are in favor of social science, it is not going to receive its fair shake.

Secondly, I think we suffer in social science, much more than hard science, from what I will call the Proxmire complaint, after Portnoy's complaint. The Proxmire complaint is that you can go through a list of social science projects and you can find the damnedest things that are being studied just by the title of them. They may be perfectly justified, but they are an object of ridicule.

Now, science, since it is not understood by the public, has a comparable set of things, but people do not understand the language at all; it is not English to the average public. So Proxmire, in his good years in Congress, did not have a list of hard science projects.

So what I am really saying is that there is a bum rap. But underneath that bum rap is sort of the basic fact that 90 percent of the work that is supported is not going to yield any practical or useful results. It may not yield any theoretical results. It is the nature of this enterprise that a lot of it is failure; a lot of it is going down the wrong alley. That is what you buy. You have to buy into a system in which a great deal of it is failure, is not achieving objectives, or——

Mr. WALGREN. That is no different than the hard sciences, I am sure, in fact.

Mr. GORHAM. No, it is not. That is comparable for both, exactly.

Mr. WALGREN. In fact maybe even more so for the hard sciences.

Mr. GORHAM. But in the hard sciences there is a tradition—in the very hard sciences—of saying, I don't know if this is ever going to be any good to anybody, and I don't care. Social scientists don't have the power, the hutzpa, to be able to say that. Most of them are forced into taking what they are doing and trying to connect it to some reality, and sometimes it is so obscure, it is not believable.

Mr. WALGREN. Thank you.

The gentleman from California, Mr. Brown.

Mr. BROWN. Gentlemen, I would just offer a word of caution about your seemingly united view that the structure of the NSF is the cause of the low budget. We may have a chicken-and-egg situation here. Of course, I recall clearly the drastic cutbacks in funding in the early eighties, and I suspect that when you had programs that did not have any money, you did not need assistant directors to run them. If you have a program that has got a lot of money, you will get assistant directors to run them.

The question that I would really like to ask is, to what degree can you enlighten us as to other sources of support for research in the areas that you represent? For example, the degree to which there is mission-related research in other areas such as Defense, which used to have a vigorous social science research program, Health and Human Services, law enforcement, all of which would seem to have a legitimate demand to support certain research.

And, secondly, to what degree has there been an increase or decrease in research support from the private sector? Again, you can make a strong case that relevant social science research would be beneficial in terms of market planning, whatever other excuse you want to use. Obviously, more enlightened policy decisions in the private sector lead to greater profitability, and some of the changes that we see developing in our industrial structure with regard to productivity are fundamentally based upon a more enlightened understanding of how people work in organizations, which is, I would think, a researchable subject. Some of the examples that you have given point to some.

Dr. SIMON. Go ahead.

Mr. SCHULTZE. I am trying briefly to do my homework.

Let me simply note, without even trying to summarize, that there is a useful discussion of at least some of the things you suggested, Mr. Congressman, in an appendix to the National Resource Council report on the behavioral and social sciences.

Mr. BROWN. You are motivating me very highly to read that report myself.

Mr. SCHULTZE. That is right. Well, it might help if you started at the end here to answer that question. [Laughter.]

Mr. BROWN. All right.

Mr. SCHULTZE. First, what I can tell you is a little bit of impressionistic view of the support coming from another major source, namely some of the large foundations who typically have supported social science research. I do not have the numbers, but my impression is that, if you adjust for inflation, that that support, over the past 25 years, has tended, I think, gradually down. Now, it may have leveled off recently; I am not sure. But my impression, for example, comparing the mid- to late 1960s with the current time, that support is much less generous, and there has been a major source of support because it has less strings attached to it.

If you get outside of NSF, going to the Federal Government for research support has some disadvantages in terms of the strings attached to it; that the program administrators, naturally, in the Federal Government want to specify very carefully what they want you to do, and you have much less freedom, although maybe Bill Gorham can speak to that better than I can.

So NSF support is tremendously important precisely because it is, in a sense, much more general, much less tied, and partly because it is basic. So it doesn't answer your question, but it gives you some sense.

Dr. **Simon**. May I add a few words to that?

First, with respect to the foundations, I am quite sure Mr. Schultze is right. They have turned much more to trying to affect human affairs—that is, action programs—and away from the support of basic research to a substantial extent, and I think there has been a downward drift of support for social science research and particularly for basic research.

As to the NSF role, NSF accounts for about a quarter or a little more than a quarter of the total basic social science research but a very small fraction of the applied research, 2 or 3 percent. So there are indeed other agencies, many other agencies. With respect to basic research, the other big supporter—I don't know whether it is surprisingly or not—is the Smithsonian Institution.

Now, of other agencies one might look to—for example, at one time NIMH was a major supporter of basic as well as applied social science research. Its functions have become much narrower over the years and much more pointed at applied problems, at immediate application of problems, and I think the same could be said of the other end-use agencies.

So the particular need that exists today is a need for making sure that that foundation is in place of basic research, recognizing that in the social sciences basic research is not necessarily as far from application as it is in many of the natural sciences.

Mr. **Brown**. Mr. Chairman, I have no further questions to ask of this panel.

Mr. **Walgren**. Thank you, Mr. Brown.

The gentleman from New York, Mr. Boehlert.

Mr. **Boehlert**. I would like to ask all the panelists a two-part question. NSF right now is talking about expanding its behavioral and social sciences funding by making it a feature of Foundation-wide initiatives like global change.

That prompts two questions: one, is this the right approach? And, two, will this allow the behavioral and social sciences to set the right research priorities?

Dr. **Simon**. I happen to be involved in a somewhat peripheral way at the present moment in the response of the National Academy of Sciences to a request from this Congress for a study of the greenhouse effect, which is part of our global change.

It is true that there is a very important social science component to social change, namely, what are its consequences for human beings and how do we react to those consequences; what policy options are present? Those problems are not really very addressable until we get much farther along on the questions of what the global changes are going to be. The evidence on that is still in an extremely chaotic state.

I have heard the word "hard sciences" here this morning. I prefer to use the word "natural sciences" because they are far from hard as soon as you walk outside of a laboratory into the laboratory of nature and worry about how you apply those hard sciences to really complex problems like the problem of what is happening to our atmosphere and our environment. They get exceedingly soft at exactly that point.

For that reason, I do not think that very much of the social science budgeting in NSF can profitably be channeled through these routes in the coming years. What we need is basic support for basic understanding about human beings as individuals and in our society, and that is what we have been getting too little of from the NSF.

There are not merely soft truths in the social sciences; there are some things we are learning, that we are learning very well and very precisely, and which are going to get softer when we apply them to complex social issues, just as natural science knowledge gets softer when they try to deal with what the oceans are doing and what the atmosphere is doing.

Mr. GORHAM. I agree with Dr. Simon on not trying to make believe that by stating important national objectives or global issues that we divert attention from the fundamental purposes of NSF.

However, I would just point out a bit of history. Jim Shannon made of NIH something from a peanut into a mountain, and the way Jim Shannon did that was that he was interested in basic biological sciences. The way in which he got political support for increasing basic biological science from virtually nothing to billions of dollars was by creating institutes named after diseases.

In point of fact, the way in which money was allocated at NIH had very little to do with those diseases, but because the packages were named after diseases that could easily be identified, people began to say, yes, of course, do you want to put the money for cancer down? The money for cancer has got to go up.

But if you looked at what the Cancer Institute did, it did an enormous amount of fundamental biological research. Indeed, once the monies for the particular disease-centered institute were given, they could then reshuffle them, and you could be placed under any institute, if you were a recipient, which happened to have the money.

Now, I point that out because the fact of the matter is that if NSF began to organize their work around sort of the equivalent of their "diseases," they might find that the public and the Congress, following the public, would be much more willing to see very substantial increases in those budgets, because they just attach the increase to the problem of concern.

Mr. BOEHLERT. Are you suggesting, then, that perhaps the behavioral and social sciences need a better marketing program?

Mr. GORHAM. That is exactly what Jim Shannon—Jim Shannon was a brilliant marketer/scientist.

Mr. BOEHLERT. Mr. Schultze?

Mr. SCHULTZE. I just thought that if we had the Depression Division at NSF, you could have both behavioral sciences, internal depression, and economists working together.

Mr. GORHAM. Right, exactly. [Laughter.]

Mr. SCHULTZE. I think a Prosperity Division would be better than a Depression Division.

Dr. SIMON. But I should point out that the NSF, which is organized primarily by scientific disciplines and not in these more marketable, as we call it, ways, has in fact gotten very strong support from the Congress in recent years and has had a very fine increase in its budget.

Mr. BOEHLERT. Stronger support from the authorizing committee than the appropriating committee.

Mr. GORHAM. Inevitably.

Dr. SIMON. That is true, I guess.

But the social sciences, organized in exactly the same way, have not shared in that prosperity, and so I think there is more than this marketing problem for basic science. I think there is a specific problem of persuading you and the others who are decisionmakers in this society that social science is good science, and it has something to offer for the society.

Mr. BOEHLERT. Well, we have come a long way. I can recall the days before I came here—I am in my seventh year now; I was a staff member for a number of years—that when NSF was on the floor, we would always have the latest report from the Golden Fleece Club, and there would be a lot of controversy, and there were some diehards that would continually oppose NSF.

Now I am pleased to say, thanks in large measure to the work of this committee, when the NSF authorization bill is on the floor, there is near-unanimous support and appreciation for the work that is being done in all disciplines. Obviously, some are being short-changed, as you feel.

Thank you, Mr. Chairman.

Mr. WALGREN. Thank you, Mr. Boehlert.

Mrs. Morella?

Mrs. MORELLA. Thank you, Mr. Chairman.

I am just curious about the NSF-funded data bases. How important are they to the work of social scientists? And are they being kept up?

Mr. GORHAM. They are the lifeblood of the social scientists, is what they are. The evolution of data bases like the PSID, the income dynamics panel, is the material from which social scientists can understand the world. NSF support for basic data collection and data collection methods could not be more fundamental to advancement of our understanding.

If I had one vote to cast or ten votes to cast, I would cast every vote for increases in data base spending. It is hard to waste money, given our current sophistication, on the kind of data that is needed. There is a long queue of things that are needed. Almost all of it would have very high payoff.

Let me give you one example, which is, we have a cycle of poverty. That means the children somehow follow the parents into poverty. But we do not really understand exactly why that happens, why some children do not and some children do. If we had a longitudinal data base of children in poverty, we would be able to understand those key decision points in which some children go right and some children go wrong and focus on those.

Mrs. MORELLA. Thank you.

Mr. SCHULTZE. Could I just add a little bit? I am carrying coals to Newcastle, I am sure, but what is terribly important for both business firms, on the one hand, and individuals and families, on the other, are longitudinal data bases.

Now, for many years social scientists worked principally with what we call time series. You just get data over time on some aggregate—sales, GNP, income. Secondly, snapshots, cross-sectional data, like a census.

But it turns out the use of either of those is subject to severe limitations because what you cannot trace is the same firm or the same individual over time and look systematically as you group them at the responses to various developments.

Now, over the past 20 years, with important NSF support, those are being developed, but there is a long way to go. Let me give you two areas. One, leveraged buyouts, mergers and acquisitions. A tremendous issue of public policy. If, over the years, we had had a good longitudinal data file on firms, particularly their financial data and their results by way of profits, sales, we could begin to tell people much more than we now can what have been the consequences for good or for ill, or some good, some ill, broken out different ways. We make stabs at it, and we are working at it, but we could use data there.

Secondly, while there is data, much more data of a longitudinal nature would be helpful to deal with the following question: In the United States, which never was a high saving country, the rate of private saving in the last 6 years—really, it started down in 1975—I say collapsed, but that is a little dramatic—but has come down very substantially, and, my gosh, combined with the Federal budget deficit, it has made us a pitifully low saving Nation.

But the best research I know of, using mainly time series or cross sections, has been unable to give us any kind of really good insight into why that private saving rate did collapse. I can tell you 15 reasons that I have seen cited and probably knock down 15 of them. But we could again do very practical—it is basic, on the one hand, because you have got to know something about how the system works, but it has tremendous fairly quick, I think, payoffs by way of better understanding for the Congress and the Executive.

Those are two examples of where that kind of data——

Mrs. MORELLA. And polling only reflects a snapshot of the moment, then. Is that what you are saying?

Mr. SCHULTZE. I am saying——

Mrs. MORELLA. Polling, to do sample polling, let's say, of savings and——

Mr. SCHULTZE. If you only do it once. What you have to do is following the same sample of families or firms over many, many years. There is, for example, one—I am not terribly familiar with it—but one that has followed high school graduates from 1972 on, getting data. They have data on the parents' income and background. They now have data on their employment record and wages, and we are beginning—I have seen some very interesting work in terms of saying what do colleges contribute to education, what aspects, what majors that people take; what do their grades do?

So when you can trace individuals over a period of time, or, conversely, firms, you can learn much more than you can by asking a poll and then, 6 months later, 3 years later, asking a completely different group of people the same questions. It is not the same thing.

Mrs. MORELLA. Thank you.

Did you want to comment, Dr. Simon, or do you just associate yourself with their remarks?

Dr. **Simon**. Just briefly. I think every report on NSF and its research, when asked what needs to be expanded, has put a very high priority on the data bases, and for the reasons that have been stated here.

There is one auxiliary thing. There has been concern from time to time about the data bases and the relation to privacy in our society. One of the important methodological advances in behavioral sciences has been to find ways in which samples can be traced over years without any dangers of disclosure of information upon individuals, and cooperative systems whereby Federal sources of data can be tapped with those assurances of privacy.

Those kinds of technical advances in the way we handle data and the way we face the other needs of the society make it more attractive than ever to really try to build up a data base of understanding of what is happening in our society.

Mrs. **Morella**. And it makes it even more important to adequately maintain and have quality assurance in it, too, and I would imagine that you would all answer yes if I said, is that proceeding correctly? So I will not ask it. [Laughter.]

Thank you, Mr. Chairman.

Mr. **Walgren**. Thank you, Mrs. Morella.

The gentleman from North Carolina, Mr. Price.

Mr. **Price**. Thank you, Mr. Chairman.

I am certain that all of you have heard the accusation from time to time that social science pretty much amounts to organized common sense, so, Dr. Simon, I was especially interested in your comments and Mr. Schultze's as well, that social science findings in fact often are counter-intuitive and often fly in the face of what passes for common sense.

It reminds me of a session I was a part of last week. As you may know, the Library of Congress has been organizing a series of symposia in honor of the Congress' 200th anniversary, and the organizing theme for those discussions has been "Knowledge and Power."

I was privileged to comment last week on a paper which Alan Schick had put together on the kinds of knowledge that Congress and policymakers in general find it useful to work with. He drew a contrast between what he called ordinary knowledge, what I guess is sometimes called the conventional wisdom, and policy research, and his conclusion was that policy research often fared rather poorly when it conflicted with the tenets of ordinary knowledge.

The conclusion that he drew was, first, that it was important to push forward with convincing and clear policy research, but also that it was important for those engaged in policy research to take very seriously the task of translating that research into usable terms, into terms that could influence policy debate. Incidentally, Mr. Gorham, he gave the Urban Institute very high marks for doing just that.

I wonder if you could reflect on that. How do we promote the use, the dissemination, of the knowledge that social scientists are generating? Have we done a good enough job of making this policy research accessible and usable? Could you reflect on that, because we do face a problem here, I think, that is widely recognized.

Dr. **Simon**. I might comment on just one aspect of that. I think the comment was made earlier, and I don't remember whether it was Mr. Gorham or Mr. Schultze who made it, that a great deal of our use of social science comes through its diffusion very broadly through the population and through institutions in our society. Mr. Brown mentioned the use by private organizations of social science information in their marketing and their other activities. I think that is very important.

Therefore, it becomes vitally important to get a level of understanding of these matters in a broad slice of the population through their own educational experiences. One of the real problems in doing that is that students are almost exposed not at all to modern social sciences today until they reach college level. The young person thinks he wants to become a scientist, for example; he or she can learn all about physics, chemistry, biology, but not about social sciences, with rare exceptions.

It seems to me that one of the things we might look to when we are talking about improving science education in our society is improving social science education so that the findings of social science have meaning to a wider circle of people in our society and can enter into public discussion.

Most of the kinds of policy recommendations that social science provides are the kinds of things that go into the political arena and that go into legislative or regulatory discussion, and many more people than the social scientists have to understand them.

Mr. PRICE. A related question is to what degree we find within the social science disciplines themselves some resistance to applied work. I know from personal involvement in setting up a public policy department which drew from political science and economics and social science and other disciplines that many academics welcomed the addition of such a department, such a major; others resisted it. It does seem to me that there has been, at least in the past, some ambivalence within the disciplines themselves about this translation into practical and applicable terms.

Dr. Simon, you, of course, are very properly addressing the broad public awareness of some of these matters. I think we are also talking about the kinds of people we are training and the kind of research that they are inclined and encouraged to do.

Mr. SCHULTZE. You are exactly right. In fact I had, myself, been worried within the economics profession, at least, of the tendency for all of the promotion incentives at the major Departments of Economics in the best universities to go toward publishing very technical, very abstract work, much of which is necessary at times, but virtually all of the effort was going in that direction, if I can exaggerate a little bit, and people who wanted to do applied or policy work had to worry about their own future.

That, I think, finally is turning around some. If you look at some of the brightest younger stars in the economics profession, many of them at an early age now are coming up and doing applied and policy work of a very good type.

The American Economic Association has begun to publish a journal which is, in effect, a translation journal. It is called the Journal of Economic Perspectives, precisely to bridge between the highly technical, highly abstract work and the understanding not merely of the public but of the broad bulk of the profession, many of whom do not specialize in some of these narrow areas.

So I think you point to what was and still is a serious problem of a lack of attention and a lack of promotion incentives within universities toward doing applied and policy work, but I think, also, there are hopeful signs that that is turning around.

Mr. GORHAM. Just to add a word, I think that probably we have to satisfy ourselves that a great deal of the work that is being done will never be interesting to the public. In my organization, which is a policy-oriented organization, we work on problems. We talk about the homeless and the medically uninsured. Those are things that the man on the street would understand.

But even there, so much of the work, the product, is intermediate; it is not final. The intermediate product is not interesting to the public. So there will always be a bulk that is going to be not interesting no matter how talented, no matter how much, as Red Smith says, little beads of blood come on the head when they try to write it to be interesting.

But the point I would make, though, is that the media has changed a lot, and the media, at least the media from the high-quality media, is really getting very good at tapping the policy research organizations and drawing it into the public. The news magazines, all of the news magazines, and some of the better television programs really are pulling from—these are giving a tremendous assist to the policy work that is being done around the country.

Unfortunately, it may be a Washington phenomenon that we think it is much better than it is. It is harder to find in Topeka. But programs like "All Things Considered" do cover an interesting array of public policy, and that does go all over the country, and it does get a good following.

Mr. PRICE. All three of you helped us considerably, I believe, by the specificity of your testimony. All of you concentrated on specific examples of research that does feed into the policy process.

All of you have also, I am sure, been involved in reviewing NSF applications, reviewing proposed research. I wonder if you could give us some indication of research proposals not funded, promising ideas that you have seen go begging because the support was not there.

Related to that is the claim that we sometimes hear that social scientists often do not submit proposals because they are aware of the low levels of funding and do not feel that their efforts in drawing up proposals are likely to be rewarded. Could you comment on that?

Mr. SCHULTZE. I want to beg off because I have a conflict of interest, having several eminently marvelous proposals from my institution before the NSF, so I think I had better not comment.

Dr. SIMON. I suppose the problem of people not making proposals because they think there is a very low level of funding is a problem, and it is probably the greatest problem in those parts of the NSF which have the smallest funds. But when we look at the rejection rate, the percentage of the proposals that can be accepted in the NSF, I think there is no lack among the proposals routinely being submitted to the NSF among ones which would make for very excellent, top-notch research if the budgets were increased.

Mr. PRICE. How do the rejection rates in social sciences compare with other areas?

Dr. **Simon**. I don't have the exact numbers before me, but I have seen numbers in the last month or so which suggest that they are perhaps about ten percentage points lower than the average. But if somebody has the real figures, they had better correct me on that. They are somewhat lower than the average.

About 10 years ago, I was involved in chairing another Academy study or NRC study of the social and behavioral science programs in the NSF. At that time we went through with a fine-tooth comb and sampled the actual applications and found just very large numbers of excellent research projects that could not be supported at that time.

Mr. **Schultze**. I think—I think—that there is a selection process going on, that the rejection rate—I believe I am right—in the economics area is about 70 percent. Now, I think I am right on that.

But that does not mean, if the funding increased, that that rejection rate would change very much, because I do think, over the years, people get to have some sense of what their chances are and submit that way. So that there is a plentitude, I am convinced, of important, rigorous research out there waiting to be done, and I am not sure the rejection rate, even if it were lower, would tell you a lot about how much good research is out there waiting to be done, because people sense—they know they have one-third of a chance; do you or do you not take it? I am not sure the rate is a good indicator.

Mr. **Gorham**. Most of my experience is with policy-oriented work and not with basic research. On policy-oriented work, there really is a dichotomy. There is cheap work and expensive work. The cheap work is work that is work on existing data bases, good ideas in policy research on existing data bases. I have never seen a really good idea that could not be funded on existing data bases. I have seen many wonderful ideas, important ideas, fundamental ideas, that required data development, and they had a great deal of difficulty because they are expensive, relatively.

Mr. **Price**. That is very helpful.

Finally, let me ask about this focus on competitiveness. That is the current buzz word around here, and of course, NSF itself justifies many of its budget requests in terms of their ability to contribute to our Nation's economic competitiveness.

I wonder, first, if you could comment in general on the ways social and behavioral research contribute to this national priority. Also, perhaps, comment on how comfortable you are with that current focus as a rationale for the work we are doing in the social and behavioral sciences. Is it a rationale that constricts us in acceptable or short-sighted ways?

Dr. Simon?

Dr. **Simon**. I guess I would be comfortable if we tried to focus all or even the major part of our basic social science research on a particular current hot issue—productivity, competitiveness, or whatever it might be. We really have to ask what the issues are going to be over a longer period, and those issues change.

On the other hand, there are, of course, many very fundamental and researchable issues involved in the productivity. Just to mention one, I think the comment was made earlier that there seems to me a little bit of evidence that a major part of the productivity problem has to do with managerial styles, managerial methods, managerial skill.

Now, there are numerous opportunities in the world right now to study what happens when you have an organization which brings two cultures together, a Japanese management group in a California automobile plant, or vice versa, an American group operating in a foreign country, where you can really see what the cultural differences are, where you can really understand what effect they have on the management practices.

There is remarkably little research funded today for doing that sort of thing. I have been able to track down one careful study that is being made of the California Toyota-General Motors joint venture. But there are numerous opportunities to substitute there these casual opinions we have of who killed Cock Robin and why we are not competing with a basic study of what it is that makes an organization tick.

I do not see much of that happening, and I suspect a major reason it is not happening is because of the difficulty of funding, particularly, field research of that kind. It is not neat and clean in the way that laboratory research is; it is not tidy; and it is expensive.

Mr. PRICE. Mr. Schultze?

Mr. SCHULTZE. It is hard to add to that. I start with a slight disadvantage because I don't like the idea of competitiveness as a concept, so that makes it a little hard for me to answer.

That is, if America had absolutely no foreign trade, we ought to be worried about the fact that our productivity is not growing very rapidly. And it doesn't make it any better or any worse that we have more or less foreign trade than we did 15 years ago. So, worrying about the problem—it is important, not only but very importantly, productivity, and we ought not to be concentrating only on our export industries.

Having said that, I think, on the one hand, there is a tremendous amount of potential contribution that can be made toward improving productivity, but only indirectly, as we learn more and more about the relationships in particular between firms and workers, about organizational problems and what does and does not make a "successful;" organizational response. All of those sorts of things are the kinds of things that will ultimately feed in and help us, bit by bit.

I am a little worried if we, however, begin to direct our research that much by end product, because very often the best results come out of things that surprise you. You learn not because you went out to study competitiveness or productivity but because something somewhat more fundamental about, for example, the relationship between workers and firms and how that contributes to productivity, or whatever else—it is going after those fundamental relationships and concerns and organizing your research that way rather, I think, than directly, for basic research, at least, organizing it by productivity or whatever the current kind of this year's problem is.

Mr. GORHAM. I share Charlie's concern about organizing life so that we compete better with the Japanese or anyone else. However, I think, in some aspects of our lives, any goal that we can use to do things that are worth doing for their own values should not be thrown away lightly.

I think of education and educational performance as a case in point. We can learn a lot, and we can do a whole lot better. You don't have to do a study to figure that out. To use the performance of Japanese children in schools, I have no problem with that, and we will be very happy to attribute efforts to improve our education, our educational systems, pointing to the need to do so because it will help us in our productivity and in our performance economically.

Mr. PRICE. Thank you for some very helpful testimony.

Thank you, Mr. Chairman.

Mr. WALGREN. Thank you, Mr. Price.

The gentleman from Virginia, Mr. Slaughter.

Mr. SLAUGHTER. No questions.

Mr. WALGREN. Well, we could go on for a long time, and I am getting concerned about the other panels, but I want to thank you all for being a resource to us. We know that we feel close enough to you that we can get with you and develop other thoughts that might make sense.

So, on behalf of the committee, thank you very much for joining our process.

Let me call the second panel: Dr. Arthur Walker, the chairman of the NSF Advisory Committee for Astronomical Sciences, associated with Stanford University; Dr. Paul Vanden Bout, the director of the National Radio Astronomy Observatory; Dr. Sidney Wolff, director of the National Optical Astronomy Observatories; and Dr. Tor Hagfors, director of the National Astronomy and Ionosphere Center.

Gentlemen and Dr. Wolff, thank you very much for joining us. Do we have our names right down there? All right. We appreciate your coming and talking with us about your various areas that you see and concerns that you have.

Written statements will be incorporated and reproduced in our transcript, and they will be available for the people who work with these records, and so you don't need to feel that you have to read the whole written script. If you want to focus in some way in your oral testimony on points that you would like to underscore, feel free to do so.

Let me ask you, we will go through the group in the order in which I introduced you to the record, so we will start with Dr. Walker.

STATEMENT OF DR. ARTHUR B.C. WALKER, JR., CHAIRMAN, NSF ADVISORY COMMITTEE FOR ASTRONOMICAL SCIENCES, AND PROFESSOR, CENTER FOR SPACE SCIENCE AND ASTROPHYSICS, STANFORD UNIVERSITY

Dr. WALKER. Thank you, Mr. Chairman and members of the committee, members of the staff.

I would like to thank you for the opportunity to testify, and I would like to try to address the issues that the chairman mentioned in his invitation. I would like to start out with a discussion of the objectives of the NSF-supported research in astronomy, and I would like to emphasize several aspects of that research.

First I would like to emphasize the fundamental importance of astronomy in the discovery of basic physical law. Often we think of astronomy as somewhat detached from our usual concerns, but it is important to remember, for example, that Newton was trying to understand an astronomical problem when he discovered the laws of gravity. Hans Bethe was trying to understand the source of power for the sun when he investigated thermonuclear reactions.

In astronomy, it is very important because it presents us with unique physical problems and physical situations which we cannot reproduce in the laboratory. Astronomy has a very important role, then, in uncovering physical law in a very basic way.

Another important role of astronomy is in technological development. Astronomy is a very highly technical discipline in terms of the observational techniques. There are many examples of this connection between technology and astronomy, reconstruction of images, development of radio receivers, development of techniques for the construction of large telescopes—which, incidentally, have important applications in defense—development of detectors and development of techniques for x-ray and ultraviolet imaging; all of these are areas where astronomy has made important contributions.

Then I would also like to emphasize the role of astronomy in education, and in particular training of technical manpower. Many aspects of technical enterprise have astronomy-trained individuals filling important roles. One can see this just in surveying, for example, my own students, many of whom have gone into defense-related or high-technology-related areas.

Another important role of astronomy is in attracting young people to scientific careers. I often teach introductory astronomy courses at Stanford, and I am always surprised at how many of our students have built or purchased their own telescopes and have in fact introduced themselves to science through astronomy and have in fact chosen scientific careers, not necessarily in astronomy but scientific careers in physics or chemistry or engineering, because of their initial attraction to science through astronomy.

I think that the NSF astronomy division does an outstanding job in addressing all of these objectives. But, unfortunately, the resources available to them are simply inadequate to the task.

I would like to turn to a discussion of the support level first, and I would like to do that by comparing the results of the last several years of NSF's astronomy support with the blueprint laid down for the 1980s in the last report of the National Academy of Sciences' Astronomy Survey Committee, chaired by Professor George Field of Harvard.

As you know, that report laid out a number of objectives, the result of a very careful selection among many objectives in astronomy, and those objectives related to two areas: first, the development of new facilities, and second, what the report called prerequisites for research.

In the first area, development of new facilities, I would say the record is somewhat mixed. The very large baseline array radiotelescope is under way, although not at an optimum pace. The proposal or priority for the development of moderate-size telescopes is now under way, with partnerships between the NSF and universities.

A millimeter wave antenna has been put into operation recently in Hawaii. Unfortunately, perhaps the most important recommendation, that for development of a large-aperture optical telescope, has not really moved forward. In fact, due to budgetary constraints, the National Optical Astronomy Observatories recently disbanded its advanced development group, which was charged with the development of a plan for this new telescope.

So, being a professor and having a penchant for grading things, I would say that perhaps we would deserve a B-minus grade in regard to development of new facilities.

Now, in regard to prerequisites for research, by which the Field report meant, for example, the support of ongoing basic research, the upgrading and maintenance of our research facilities, the development of capabilities for computing, both for the analysis of data and for theoretical research, the development of new technology for observations, and perhaps most importantly, the support of young people entering the discipline of astronomy, I am afraid I would say that our record is really quite dismal.

The level of budgets for all of the physical sciences has been level, taking inflation into account, over the last 5 or 6 years; in astronomy; that level has actually declined. In fact, the level of support for basic research in the astronomy centers and also at the universities declined someplace between 15 and 20 percent in terms of real dollars or inflation-adjusted resources.

This has been masked to some degree by the fact that the construction monies for the VLBA are part of the astronomy budget, and so it would appear that the astronomy budget has declined only slightly in real terms, but in fact there has been a 20 percent decline virtually across the entire discipline, and this has had disastrous effects for us over the last several years.

There have been almost yearly layoffs at the National Observatories, so that each of those observatories is now very drastically understaffed.

Maintenance has been deferred on all of the National Observatories, and there are many very serious maintenance problems. There has been a failure to start a number of very important new programs. The National New Technology Telescope has not been started; the solar global oscillations network program is just barely under way; a very important upgrade to the 1,000-foot telescope at Arecibo has not been undertaken.

And, finally, this has had very serious consequences for university-based research. It has resulted in a reduction of the number of research programs and cutting of the budgets of those which have been approved. This is a very serious problem not only for research but also for the support of the education of graduate students.

It is particularly depressing because of the enormous opportunities available to astronomy just at this time. There are several reasons for these opportunities. There has been a very important partnership develop between ground-based and space-based observational techniques. It has led to many new discoveries, for example, the discovery of a very large amount of hot gas in clusters of galaxies, which represents as much as half of the visible matter in the universe, and understanding of the consequences of that.

There have been new techniques developed such as the study of the oscillations of the sun to determine the internal structure of the sun. And it has also led to the understanding of many older problems such as the energy source for quasars. But, unfortunately, these opportunities are not going to be available to us unless the level of the budget is increased.

A number of new technologies have been developed, especially, for example, the capability to develop very large mirrors. It appears as though those new technologies will be exploited not first in this country but in fact first in Japan and Europe.

Now, I would like to turn to the question of the priorities for instrumentation in astronomy. I have set up my own list of priorities, which I think many astronomers would agree with and which I think is consistent with the Field Committee report.

I think the first priority would be to go forward with the development of two 8-meter optical telescopes. Because we have not been able to start the new technology 15-meter equivalent aperture telescope, I think an alternative plan, which has been to develop two 8-meter telescopes, has been put forward, and I think it is very important for us to start on that as soon as possible.

It is also very important to go forward with the Global Oscillations Network in order to study the internal structure of the sun. The internal structure of stars is a very fundamental theory of astronomy, but it is virtually untested, and this new technique of studying the internal structure of the sun by studying the oscillations of the solar surface is extremely important and will have very profound effects for all of astronomy.

My next priority would be to go forward with the development of a replacement for the 300-foot telescope which collapsed in Green Bank, and I would link that to an upgrade for the 1,000-foot telescope at Arecibo. These two facilities would make a very, very powerful complementary set of facilities for study of a wide range of problems in astronomy, galactic astronomy problems, including the distribution of the interstellar matter, also the study of a very large-scale structure of the universe, which has very important consequences for our understanding of how our universe evolved.

The final priority that I would recommend to you would be the development of millimeter wave interferometer. That is a project which is not quite yet ready technically. There are two smaller interferometers now under construction through the grants program, but I think once those have been proven, it will be time to develop a national facility which would complement, at the shorter wave lengths, the very large array.

Now, each of these first three initiatives, I think, is ready to go forward now.

I would like to close by making some comments on the link between research and education in astronomy. These are very closely linked because graduate students in astronomy are almost entirely supported by research funds, mostly from the NSF and from NASA.

With the cutback of the number of grants and the size of grants as a result of the significant decrease in the effective spending power of the Astronomy Division of the Foundation, many principal investigators have had to make the difficult choice between supporting graduate students and supporting young researchers just having received their Ph.D. entering the new profession. In most cases the choice has been to support graduate students, but you can see that this very difficult choice is bound to have a devastating effect on trained manpower available to astronomy and other areas of technology in the future.

So I think that I want to leave you particularly with an understanding that, although we have made progress in developing important new facilities, the basic program in astronomy is a disaster. It has been cut back severely. We have had layoffs at the National Observatories, and many very worthy grant proposals are not being funded, and I think, unless this is reversed immediately, it will be many years before we are able to repair the damage currently being done to the basic infrastructure of astronomical research in the country.

[The prepared statement of Dr. Walker follows:]

Statement by Arthur B.C. Walker, Jr.

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Professor Walker is currently Chairman of the
NSF Advisory Committee for Astronomical Sciences

Mr. Chairman, Honorable Members of Congress:

Introduction: In my testimony before your Subcommittee last year, I expressed my concern that the funding available to the basic research programs in physical science supported by the National Science Foundation over the period 1985-1988 has been constant in inflation adjusted dollars (after a period of growth between 1982 and 1985). In my own field, astronomy, the inflation adjusted level of funding has, in fact, declined. Unfortunately, in spite of the Congressional endorsement of Mr. Bloch's plan to double NSF funding over the five year period starting in 1989, the 1989 and 1990 NSF spending plans have not significantly altered this very alarming trend in support for the physical sciences. My remarks on the impact of the 1990 NSF budget will be directed primarily to astronomy, as you have requested, and as appropriate to my own experience and knowledge, however, I wish to emphasize that the issues raised by insufficient support of basic research in the physical sciences (and necessarily, therefore, insufficient support for graduate education) transcend the problems of the individual disciplines, (physics, astronomy, chemistry, material sciences, and mathematics).

In his letter of invitation, Chairman Walgren asked that I address six issues:

1. The objectives of the proposed NSF research program in Astronomy
2. The adequacy of support for Astronomy by NSF in light of the national and international research effort in Astronomy
3. Current research opportunities in Astronomy
4. The ways that research in Astronomy contribute to the advancement of other fields of science
5. Priorities for new astronomical research facilities, with emphasis on the replacement of the 300 foot radio telescope at Green Bank
6. Research and education programs in Astronomy.

I will briefly comment on each of these issues.

Research Objectives: The staff of the NSF Division of Astronomical Sciences, with the assistance of the National Centers, and of astronomers from every area of our discipline who serve on a variety of advisory committees, have developed an exciting long-range plan. We are fortunate to have an excellent blueprint for the direction of our discipline in the form of the report of the last Astronomy Survey Committee of the National Academy of Sciences (this panel was ably chaired by Professor George Field of Harvard).

This report has proposed a balanced program of new space-based and ground-based initiatives, support for theoretical research, and nurturing of the basic infrastructure of our discipline, including maintenance and upgrading of existing and highly productive facilities, support for students and young astronomers entering the field, support for the development of new instrumentation, and for computational facilities. These basic support capabilities were called "Prerequisites for New Research Initiatives" in the Field Committee Report. Among the primary recommendations for NSF supported facilities were:

1. Construction of the Very Long Baseline Array (VLBA)

2. Design Studies leading to the construction of a National New Technology Telescope in the 15 meter class (NNTT)

3. Construction of a 10 meter diameter Millimeter Wave Antenna

4. The construction of new Optical/Infrared Telescopes in the 2-5 meter class

5. Development of techniques and instrumentation for advanced interferometry in the ratio infrared and optical regions of the spectrum

6. Support of studies for the detection of gravitational waves from astronomical objects.

The Division of Astronomical Sciences of the NSF has endeavored to carry out these recommendations to the best of its ability, with some success. The VLBA is under construction although at a less than optimal pace. A millimeter wave antenna and two millimeter wave interferometers are in the early stages of operations, or in the final stages of development. One 3.5 meter optical/infrared telescope is under construction with some assistance from NSF, and a second is in an advanced planning stage. Plans have been put forward, within the Physics Division of the NSF, to develop a gravitational wave detector array. The Congress, and the staff of the NSF deserve credit and our thanks for this support. Unfortunately, the single most important ground-based initiative, design studies necessary for the development of a new large aperture national telescope, has not received adequate level of support, which has caused optical and infrared astronomers to modify their strategy for the development of large aperture telescopes, as I will discuss below.

With regard to the support of the Field Committee "Prerequisites for New Research," the record is considerably less positive, in fact, I believe that it can reasonably be call dismal. In their testimony, Dr. Sidney Wolff, Director of the National Optical Astronomy Observatories (NOAO), Dr. Paul Vanden Bout, Director of the National Radio Astronomy Observatory (NRAO), and Dr. Tor Hagfors, Director of the National Astronomy and Ionosphere Center (NAIC), have eloquently detailed the depressing and destructive record of continuing budget cutbacks in basic research support, inadequate maintenance of productive facilities, and the layoff of critical personnel at the national observatories. A particularly significant and devastating recent example is the disbanding of the Advanced Development Group within NOAO, the group responsible for the development of the design for the NNTT, as a result of the impact of the FY 1989 budget. Similar examples could be cited at each of the observatories. The situation is no better for the Grants Program, which supports research in the astronomy community, especially the universities. Support for theoretical research, support for new instrument development, support for the maintenance, upgrading and operation of critical observational facilities, and most tragically, support for young astronomers are all inadequate.

In summary, although a significant number of new facilities of superb quality have been built during the last decade or are currently under construction, the discipline of ground-based astronomy is literally starving to death. We have been forced, by the inadequate level of support for all aspects of our discipline, to consume our very infrastructure to find funds to continue ongoing programs of fundamental importance, and to operate new facilities. This cannot continue, and it seems to me that FY 1990 represents a watershed in this process. I must emphasize that astronomers have an unique record of shutting down older and less capable facilities, as new facilities come on line. In a recent report on the priorities of the various radio observatories within the US for NSF support, a dozen facilities that have been closed in the past two decades were cited. The problem is simply that the declining budgets (in inflation adjusted $'s) of the past five years are literally destroying the health and vigor of American Astronomy, despite the development of new facilities of the first rank. Indeed, the current situation in astronomy reminds me of the situation that the Rogers Commission, of which I was a member, found had existed in the Space Shuttle program before the Challenger Accident. NASA was literally cannibalizing the Shuttles that were scheduled to fly on future missions in order to find spare parts for the Shuttle scheduled for the next flight. This policy was certainly one of the factors contributing to the general attitude of risk taking that led to the accident. In the same way, I fear that the current NSF funding pattern of starving the basic infrastructure of Astronomy is inexorably leading us to a crisis which will so disrupt the discipline of Astronomy in the United States, that years, and very considerable investments, will be required to regain our current preeminent position. The most critical element of any enterprise is its trained people, in our case, scientists and unique and highly talented engineers and technicians. The time required to train scientists, technicians, and engineers is very long. If the chain of trained individuals is broken, by losing a generation of people at any stage of their careers, but especially those near the start of their careers, it will require many years to reestablish our basic infrastructure.

Support Level: Tables 1-4 (pages 5-6) summarize the support level over the past five years, and the current (1989) and Proposed FY 90 support levels for the major components of the NSF Astronomy program. Table 1 shows that the three national observatories have suffered an average cut of nearly 20% in operating funds, after adjustment for inflation, between 1984 and 1989. The proposed 1990 budget offers no relief, with decreased (in inflation adjusted $'s) funding for NAIC and NRAO (not including VLBA construction funds), and an increase of less than 2% for NOAO. These levels of support would be inadequate, even for a static field of research. Astronomy is, in fact, a very dynamic field, indeed all of the national observatories have developed important new capabilities. The situation is most

Table 1 NSF Funding Levels for Astronomy in Inflation Adjusted $'s

NSF Budget In 1988 $s

Year	1984	1985	1986	1987	1988	1989	1990
NAIC	7.1	6.7	6.3	6.2	5.9	6.0	5.8
NOAO	26.9	25.3	24.9	24.3	23.3	22.6	23.0
VLBA	2.9	10.0	9.4	12.0	11.6	11.5	11.3
NRAO-VLBA	20.6	19.6	18.3	17.8	17.3	17.3	17.1
Tot. NRAO	23.5	29.5	27.7	29.8	28.9	28.7	28.4
Tot. Ctr.	57.6	61.5	58.9	60.2	58.1	57.4	57.1
Grants:	32.3	30.2	29.0	29.0	27.9	27.9	28.4
Other:							
Astronomy:	89.9	91.7	87.9	89.3	86.0	85.3	85.6
NSF:	1534.5	1664.3	1670.6	1704.0	1717.0	1800.2	1955.6
De/inflator: (percent)	16.2	10.8	9.6	5.0	0.0	-4.5	-9.0

Table 2 NSF Funding Levels for Astronomy in Current Year $'s

NSF Budget In current year $s

Year	1984	1985	1986	1987	1988	1989	1990
NAIC	6.1	6.1	5.7	5.9	5.9	6.3	6.4
NOAO	23.2	22.8	22.7	23.1	23.3	23.7	25.2
VLBA	2.5	9.0	8.6	11.4	11.6	12.0	12.4
NRAO-VLBA	17.8	17.7	16.7	17.0	17.3	18.1	18.8
Tot. NRAO	20.3	26.7	25.3	28.4	28.9	30.1	31.2
Tot. Ctr.	49.5	55.5	53.7	57.4	58.1	60.1	62.8
Grants:	27.8	27.2	26.5	27.7	27.9	29.2	31.2
Other:	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Astronomy:	77.3	82.8	80.2	85.0	86.0	89.3	94.0
NSF:	1320.3	1501.8	1523.0	1623.0	1717.0	1885.0	2149.0

Table 3 Annual Changes in NSF Funding for Astronomy in Inflation Adjusted $'s

NSF Budget				Percent change versus prior year in FY 88 $s			
Year	1984	1985	1986	1987	1988	1989	1990
NAIC	NA	-5.6	-6.5	-1.6	-3.9	1.9	-4.4
NOAO	10.9	-6.0	-1.6	-2.6	-3.9	-2.9	1.4
VLBA	NA	243.3	-6.0	27.7	-3.1	-1.2	-1.5
NRAO-VLBA	-17.8	-5.2	-6.3	-2.6	-3.1	-0.1	-1.0
Tot. NRAO	-6.3	25.4	-6.2	-7.6	-3.1	-0.5	-1.2
Tot. Ctr.	16.5	6.9	-4.3	2.3	-3.5	-1.2	-0.5
Grants: Other:	26.2	-6.6	-3.9	-0.2	-4.0	0.0	1.9
Astronomy:	19.8	2.0	-4.2	1.6	-3.7	-0.8	0.3
NSF:	16.9	8.5	0.4	2.0	0.8	4.8	8.6

Table 4 Trend of NSF Support for Astronomy in Inflation Adjusted $'s

NSF Budget					Percent change vs. 1984 in FY 1988 $s		
Year	1984	1985	1986	1987	1988	1989	1990
NAIC	0.0	-5.6	-11.7	-13.1	-16.5	-14.9	-18.6
NOAO	0.0	-6.0	-7.5	-9.9	-13.4	-15.9	-14.7
VLBA	0.0	243.3	222.6	311.9	299.2	294.4	288.4
NRAO-VLBA	0.0	-5.2	-11.2	-13.5	-16.2	-16.3	-17.1
Tot. NRAO	0.0	25.4	17.7	26.6	22.7	22.1	20.6
Tot. Ctr.	0.0	6.9	2.3	4.7	1.0	-0.2	-0.7
Grants: Other:	0.0	-6.6-	-10.3	-10.1	-13.7	-13.7	-12.0
Astronomy:	0.0	2.0	-2.2	-0.7	-4.3	-5.1	-4.8
NSF:	0.0	8.5	8.9	11.0	11.9	17.3	27.4

dramatic for NRAO, which has put the VLA, the world's most powerful radio telescope, into operation during this period, and is preparing for operations of the VLBA. For NOAO, although no new major telescopes have been built, new detectors have greatly enhanced the power of existing telescopes, as Dr. Wolff points out in her testimony, and an important new technique for probing the interior of the Sun, helioseismology, has been exploited. At NAIC, plans for a major upgrade have been developed which will greatly enhance the capabilities of the 1000 foot Arecibo Radio Telescope (the world's largest radio telescope).

The problem is equally severe for the grants program, where, in spite of a 15% decrease in inflation adjusted funding, a new 10 meter sub-millimeter dish, two mm-wave interferometers, a new cosmology initiative, and substantial detector development projects have been carried out, or are in progress.

The situation of the U.S. astronomical community is in sharp contrast to the situation of European and Japanese astronomers, who have recently completed several important radio and optical telescopes, and now are about to undertake very major new optical projects which have recently been approved, most notably, the 16 meter equivalent array planned by the European Southern Observatory, and an 7.5 meter telescope planned by the Japanese. It is my understanding, as a result of conversations with U.S. astronomers who have used the facilities at European and Japanese observatories, that the level of support for the infrastructure of these observatories is significantly greater than that available for our U.S. national observatories.

Tables 3 and 4 (page 6) emphasize the trends that are most disturbing to U.S. astronomers. At a time when foreign governments (most notably Europe and Japan) are making major commitments for instrumentation, and are providing an expanding level of support for the infrastructure of astronomical science, the U.S. commitment has decreased by nearly 20%. If these trends are not reversed, there can be no doubt as to the outcome, U.S. astronomical research, which has led the world since WWII, will not only lose that position of leadership, but will become non-competitive in many areas.

Current Opportunities: Astronomy is in a unique period of opportunity, such as comes tc a science perhaps only one or twice per century. The opportunities can, I believe, be compared to those periods such as Kepler's explanation of planetary orbits, Galileo's invention of the telescope, or Hubble's discovery of the expansion of the universe. Indeed, the opportunities are now much broader, and cover virtually every area of Astronomy. There are three reasons for these opportunities: 1) the coupling of the powerful new observational techniques possible from space, with the analytical power of ground-based radio, optical, and infrared observations, have led to the discovery of many new phenomena, and the ability to probe known, but poorly understood, phenomena more deeply, 2) progress in many fields of physics has increased our basic understanding of the physical world to the point that we can interpret new discoveries and observations in terms of the fundamental laws of physics, and 3) progress in many fields, including detector technology, computing, infrared technology, etc., has provided astronomers with new tools that have been used to exploit our instruments and observational data more fully. Several examples will illustrate these new opportunities:

1. The NTT: as Dr. Wolff points out in her testimony, detector technology has improved the effectiveness of existing telescopes to the point that further improvements in telescope performance can only come from the development of larger telescopes. New techniques for fabricating low-cost light-weight mirrors of large aperture have led to the private funding of the segmented mirror Keck 10 meter telescope project by the California Institute of Technology and the University of California, and the fabrication of a 3.5 meter mirror by spin casting. The latter technology is the primary candidate for fabricating 8 meter mirrors for two new telescopes proposed by NOAO, which are discussed more fully below. Large new telescopes on the ground are an essential complement to the Space Telescope, because the Space Telescope, although very powerful for the discovery of very faint objects by virtue of the unprecedented high angular resolution it will achieve, has insufficient aperture to carry out detailed spectroscopic measurements of very faint objects. Measurements of this type are essential to such fundamental problems as identifying the nature of the energy sources in quasars, and studying star formation in very young galaxies.

2. Helioseismology: One of the most fundamental theories of modern astronomy is the theory of stellar structure and stellar evolution. Although this theory is highly successful in predicting the gross properties and life histories of stars, we have had, until recently, no way to compare the predictions of the theory on the internal structure of stars, with observations of stars. The technique of helioseismology, which deduces the internal structure of the Sun from the study of the oscillations of the Sun as revealed by the pulsations of the Sun's surface, has allowed the first such comparisons. This new technique has also been successfully applied to other stars. NOAO has begun the development of a network of observing stations called the Global Oscillations Network (GONG) which will map the Sun's internal structure and dynamics using these new techniques. This important new program is proceeding at an unacceptably low pace due to the current crisis in NSF Astronomy funding.

3. In the past several years, studies of the distribution of galaxies in space on a large scale (hundreds of millions of light years) has revealed a very large scale structure of super clusters and voids which was unanticipated. This very large scale structure has very important implications for our model of the formation and evolution of the universe, and provides a very severe test of recently proposed modifications of this "Standard Big Bang" model. The Arecibo 1000 foot radio telescope has proven to be a very powerful tool for the study of the large scale structure (as would be a replacement for the 300 foot telescope at Green Bank). A major upgrade of the 1000 foot telescope feed system and other improvements, costing approximately $20,000,000, would greatly enhance its value for the study of large scale structure. If the NSF can supply half of the funds necessary for these improvements, NASA will supply the other half. So far, the crisis in NSF funding has not permitted this work to proceed.

4. **Cosmology:** Although the standard model of the origin of the universe in a cosmic fireball or "big bang" has been successful in explaining many of the large scale properties of the universe, it leaves many questions unanswered. Recent advances in our understanding of the fundamental building blocks of matter, and of their interaction at very high energies (or temperatures) has allowed theoretical physicists and astronomers to study the evolution of the universe in the first one hundredth (0.01) second of its existence, and the imprint that events at this very early time has left on the universe. This research has raised the very exciting possibility that the questions left unanswered by our "Standard Big Bang" model can be resolved. One of these questions is the cause of the large scale structure mentioned in 3 above. Another is the phenomena which lead to the formation of galaxies. (Recent observations at ground-based telescopes using new charge-coupled detector arrays have revealed objects that may be very young galaxies.) Last year, the Physics and Astronomy Divisions jointly proposed an initiative to support an increased level of research in cosmology. Although this initiative did receive some support, the level of support does not approach the level that is justified by the importance and excitement of the field. This is one of the areas of astronomy and physics that is most attractive to advanced physics and astrophysics students, support of this type of research is critical to the training of the next generation of astrophysicists. An indication of the attractiveness of this field is the fact that a cosmology center has been selected as one of the first of the new NSF Science and Technology Centers to be established as the result of a highly competitive review process.

The four areas of research described above are illustrative of the opportunities that abound in Astronomy. Dr.'s Wolff, Vanden Bout and Hagfors have mentioned others in their testimony, and the Field Committee Report and its companion volumes provides a very readable and comprehensive summary. A new Astronomy Survey Committee is about to begin a study leading to a report for the decade of the 1990's. The new report will, I am confident, identify many new opportunities which will complement and extend those identified in the Field Report.

Contribution of Astronomy: Astronomy is a very highly technology intensive discipline. In his testimony, Dr. Vanden Bout has provided a detailed discussion of how radio astronomy has provided a variety of new technologies which have found application elsewhere. Examples are the technique of image reconstruction (Aperture Synthesis) which underlie the VLA and VLBA, the development of state of the art radio receivers and the development of time and frequency standards. The last area is an interesting case. Our fundamental time standards (the year, month, day, hour, and second) all have their origin in the motions of astronomical bodies. In the last two decades, however, atomic clocks have replaced astronomical motions as the fundamental standard of time. The recent discovery of pulsars with millisecond periods represent a physical system that may well replace atomic clocks as the most accurate standard of time. Other examples can be cited, such as the development of techniques for spin casting of large aperture mirrors (up to 8 meters) by Dr. Roger Angel of the University of Arizona, and the techniques for the construction of large aperture segmented mirrors by Dr. Jerry Nelson and his colleagues at the University of California, Berkeley. There is considerable interest in these mirror technologies by the Air Force, and others.

Although other examples can be cited, it is important to realize that starting with the work of Sir Isaac Newton, who developed his Theory of Gravitation to explain the orbits of astronomical objects, and extending to the Nobel prize-winning work of Dr. Hans Bethe, who developed his theory of thermonuclear reactions to explain the source of energy of the Sun and stars, the extreme physical conditions, and phenomena of astronomy, have been an inspiration for the development of fundamental physical theory. Complementary to this, the observational requirements of astronomy have inspired a long line of technological developments, starting with Galileo's development of the telescope, and continuing to the recent developments of infrared array detectors and of techniques for forming high resolution x-ray and extreme ultraviolet images, an area of research in which I have been active.

Priorities: There are a number of very high priority research facilities which are essential if U.S. Astronomy is to remain competitive. These are:

1. Completion of the Very Long Baseline Array (VLBA).

2. Completion of the Global Oscillation Network (GONG).

3. Construction of two 8 meter aperture optical telescopes placed at sites of high quality, one in the northern hemisphere, and one in the southern hemisphere. This development program could lead to the eventual construction of a 15-16 meter aperture NNTT.

4a. Construction of a replacement for the 300 foot Radio Telescope at Green Bank.

4b. Completion of an upgrade for the 1000 foot telescope at Arecibo to improve its sensitivity and ability to observe objects over a wider range of latitudes.

5. Development of a millimeter wave interferometer with capabilities in its wavelength range comparable to those of the VLA at centimeter wavelengths.

These projects all deserve your strongest support, and should be started (or completed) as soon as possible. I have listed these facilities in their rough order of priority, although a number of other factors, including technological issues, negotiation of funding from other sources (such as NASA for the Arecibo upgrade) or formation of partnerships with foreign collaborators (for the 8 meter optical telescope projects), will determine which projects are ready to start first.

With regard to the replacement of the 300 foot dish, I regard this as a very high priority, and I believe that most, if not all, radio astronomers in the U.S. would be willing to see the development of a millimeter wave interferometer (which is not yet technically ready) delayed in order to allow the 300 foot dish development to proceed immediately. A very strong and compelling scientific case for this facility has been made in the report "A Radio Telescope for the Twenty-First Center," published by NRAO (January 1988, R.L. Brown and F.R. Schwab, Editors). I think I speak for most astronomers when I say that I hope that an early commitment by NSF to proceed with this important project will not impact adversely the completion of the VLBA, and the development of the GONG, the NOAO 8 meter telescopes, and the initiation of the Arecibo upgrade.

Research and Education: The research supported by the Division of Astronomical Sciences at the National Centers and at the universities is very closely linked to graduate education. Support for graduate students, especially in their final years of study, comes mainly from NSF (or NASA) grants. It is important to realize that graduate astronomy training is very broad, and highly technical. Astronomy Ph.D's work in a variety of situations. For example, one of my former students became an astronaut, another is developing infrared detection techniques for a DOD contractor, a third is involved in the development of synchrotron radiation as a research tool in condensed matter physics, and a fourth is employed by a NASA center. Thus, the reduced levels of funding in astronomy will have a negative impact on our scientific manpower training, an area in which we are seriously lagging behind our industrial competitors.

Astronomy has another very important role; that is in attracting young people to science, and to a scientific career. Several years ago, I participated in a summer program at NOAO for students from minority groups that are under-represented in science. One of the students who participated in the program was a young man who subsequently applied to our Ph.D. program in Applied Physics at Stanford, and will soon receive his Ph.D. degree in Quantum Electronics. I believe that the opportunity he received to participate in scientific research at NOAO had a profound influence in his decision to seek advanced scientific training. Astronomy plays an important role in introducing university undergraduates, and high school students, to the physical sciences. Many astronomers on university facilities are heavily involved in the teaching of undergraduates. At the level of secondary schools, astronomy's impact is felt mainly through the activities of amateur astronomers (who constitute a very valuable educational resource), and public facilities such as planetariums. I believe that a more formal program of astronomy education at the secondary school level could play an important role in the attracting young people to scientific careers.

Summary: I wish to thank Chairman Walgren, and the members of the Subcommittee and staff for the opportunity to speak to you. We are grateful for the support that we receive from the American public. However, it is critical for you to understand that the present level of support for the infrastructure and research in astronomy is inadequate, as a result of six years of declining support (support has dropped by 20%, not including the construction monies for the VLBA). The FY 1990 plan does not address this crises, indeed, it continues the trend. Unless some increase in support level is incorporated into the 1990 budget, the damage to astronomical science in the U.S. may reach a level that will require many years to reverse.

Arthur B.C. Walker, Jr.

Education and Employment: Arthur B.C. Walker, Jr. received his B.S. in Physics with honors from Case Institute of Technology in 1957; he was elected to membership in Tau Beta Pi in 1955. He received the Ph.D. Degree in Physics from the University of Illinois in 1962, where he was associated with the Betatron Laboratory, and carried out research in nuclear physics and meson physics; he was elected to membership in Sigma Xi in 1960. In 1962, Dr. Walker entered active duty with the U.S. Air Force and was assigned to the Air Force Weapons Laboratory with the rank of 1st Lieutenant. At the Weapons Laboratory, Dr. Walker instrumented a rocket probe and a satellite experiment to measure protons and electrons trapped in the Earth's magnetosphere. In 1965, upon completing his military obligation, Dr. Walker joined the Space Physics Laboratory of The Aerospace Corporation as a member of the technical staff. He conducted experimentation in solar physics and upper atmospheric physics, specializing in studies of the solar x-ray flux. He was promoted to Staff Scientist in 1968 and to Senior Staff Scientist in 1970. In January of 1974, Dr. Walker was appointed Associate Professor of Applied Physics at Stanford University. At Stanford, Dr. Walker has continued his experimental research in solar and non-solar x-ray astronomy and has taught astronomy at both the graduate and undergraduate levels. He has supervised the dissertation research of five students who have received their Ph.D. degrees at Stanford. Dr. Walker is presently Professor of Applied Physics at Stanford University. He also serves as Director of the Stanford Student Astronomical Observatory.

Research: Dr. Walker's research has concentrated on the study of high temperature low density astrophysical plasmas with space borne instrumentation. At The Aerospace Corporation,. he developed several rocket and satellite instruments for the spectroscopic study of the solar corona, including Bragg crystal spectrometers flown on the Air Force OV1-10 and OV1-17 satellites, resulting in several of the earliest high resolution astronomical x-ray spectral observations, and the first astronomical identification of x-ray dielectronic recombination lines. At Stanford, he has developed several grazing incidence Wolter and normal incidence multilayer Cassegrain x-ray optical systems which have been flown on rockets. He lead the group that obtained the first high resolution normal incidence x-ray image of the sun. He has also studied the abundance structure of the Interstellar Medium.

Scientific and National Service: Dr. Walker has served on or chaired a number of NASA, National Science Foundation, and National Academy of Science Committees which prepare recommendations on the future course of astronomy and astrophysics, including the 1980's Decade Astronomy Survey Committee. Presently, Dr. Walker chairs the Advanced Solar Observatory Science Working Group for NASA and chairs the Advisory Committee for Astronomical Sciences of the National Science Foundation. In 1986, President Ronald Reagan appointed Dr. Walker to the Presidential Commission on the "Space Shuttle Challenger Accident".

Membership in Professional Associations: Dr. Walker is a member of the American Physical Society, the American Astronomical Society, the American Geophysical Union, the International Astronomical Union, the National Society of Black Physicists, and the Society of Photo Optical Instrumentation Engineers

Civic Activities and Awards: Dr. Walker served as President, University of Illinois Chapter NAACP (1960), and President, Albuquerque, New Mexico Chapter NAACP (1964). He was Co-Recipient of the 1964 Human Rights Award of the United Nations Association of Albuquerque, and Recipient of the Award of the Santa Clara Chapter of the Urban League (1987).

Major Administrative Responsibilities: Dr. Walker served as Director of the Space Astronomy Project at The Aerospace Corporation (1972-1974). At Stanford, he served as Associate Dean of the Graduate Division (1975-1981), Chairman of the Astronomy Program (1975-1980), Director of the John Wilcox Solar Observatory (1987-), and Associate Director of the Center for Space Science and Astrophysics (1989-).

Consulting: Dr. Walker has been a consultant for The Aerospace Corporation, the Rand Corporation, the Jet Propulsion Laboratory, the Lockheed Corporation, the Harvard Center for Astrophysics, the University of Alabama in Huntsville, NASA, Teledyne Brown, Inc., and TRW, Inc.

Major Scientific Projects: Dr. Walker has served as Co-Principal Investigator, Stellar Bragg Crystal Spectrometer, NASA High Energy Astronomy Observatory (1972-1974), and Co-PI, Coronagraph/XUV/X-Ray Experiment on the International Solar Polar Mission (1979-1981). He is a Co-I for the Solar Oscillations Imager on SOHO.

Current Research: Professor Walker's current research is concentrated on the physics of the solar corona and the development of new types of astronomical instrumentation.

Mr. **Walgren.** Thank you, Dr. Walker.

Let's go in the order in which I introduced you to the record, and that would indicate that we turn to Dr. Vanden Bout.

STATEMENT OF DR. PAUL A. VANDEN BOUT, DIRECTOR, NATIONAL RADIO ASTRONOMY OBSERVATORY

Dr. **Vanden Bout.** Mr. Chairman and members of the committee, I appreciate the opportunity to comment on issues in the NSF Astronomy Program. Let me begin with the issue of adequacy of support.

I can speak to the situation at NRAO. In contrast to the growth in real dollars—that is, after correction for inflation—of 20 percent since 1984 in the NSF budget, astronomy has taken for operation of its existing programs a 20 percent cut.

Now, for NRAO that means we have lost $4 million in resources to conduct our program. What does that mean? Well, it means that, for years, every year, we are searching for ways to continue to present the opportunities for observations to our users, but with less resources.

For example, you first freeze hiring and then you discover you are forced to a layoff. You try to get by with minimum wage increases and discover that you have to freeze pay scales. You defer maintenance for a year, hoping that next year will be better, discover that it is not, and you are in even worse condition than you were the year before.

You are forced to reduce equipment purchases to pathetic levels. The amount of test equipment we buy, the investment we are making in new instrumentation, is at a historic low for the Observatory now.

It means that the level of technical development activity is at a drastically cut level, lower than it has ever been in the history of the Observatory. This has a real effect in two ways. New instrumentation is the future of the Observatory, and so that is threatened. It is also threatened in that, when technical development cannot be pursued, when the opportunity to pursue new ideas is lost, then the best people you have are demoralized and begin to think about leaving; in fact, some of them have left.

There is an alternative way to look at this. NRAO's budget for operations today is what it was in 1978 after you correct for inflation. That is a little over 10 years. But there is a huge difference in the Observatory, because since 1978, the Very Large Array began operations. This is the biggest facility we operate. And so our responsibilities have increased enormously, but our resources have not gone up.

On top of all this, the Observatory is facing the operation of the Very Long Baseline Array. This is a new facility that is under construction; it is about half complete. In 1992 we will begin operation of that fully. On the other hand, the VLBA can be operated partially as antennas are completed. It is an array of ten antennas, and as each one is completed, we can contribute it to ongoing research in very long baseline interferometry observing.

So we have had to face the operation of this new facility early, before the construction is complete, and have not had the funds to do that. What little funds have been placed into VLBA operations have been taken from the rest of the budget, and we are at the limit at this point, so that in the future we face the embarrassing prospect of completing antennas and then having them mothballed until some future date when we have funds to operate them.

It is not that we are unwilling to give up things to operate new things. There is a tradition in radio astronomy, and in astronomy in general, of doing that. When the VLA was finished, the interferometer in Green Bank that was the predecessor to the VLA was closed for astronomical observing, and a number of university facilities that now do VLBI science will not do it when the VLBA is finished.

But that is not enough. If you make progress, the new facility is more advanced, it is more elaborate, it does more, and it requires more to operate it.

So what has happened is that, after 5 years of declining budgets, I think we are at the point where serious damage will be done in 1990. That proposed budget does not alter this trend, and we are going to be forced to sustain damage that will take years to repair.

I think it is tragic in that the National Centers in Astronomy serve a large community, and they serve them well. They have contributed a good deal to technical development, and in my written testimony there is an attachment that outlines that for radio astronomy. Many of those people are now looking elsewhere because there is so little they can do at the Observatory in development work.

Even more important, I think, is the fact that the future of the field as a whole is threatened when the Centers are threatened because there is a cadre of people who enter the field and have not established themselves in the sense that they have grant support at universities. It takes a while to establish yourself, and the grants program at NSF is very tight, as well as the budgets for the Centers, and so it is only able to support very few people. So there is a large group of people that depend on the National Centers as the place where they can do their science and prove themselves and some day get a grant.

We do not operate those Centers for ourselves. Our staff uses some 10 to 15 percent of the observing time. Most of it is used by outside observers. If that opportunity is lost to these young people who are building their careers, I think it will have very serious consequences for the future development of the field.

Well, that is the issue of adequacy of support. The other issue I wish to address is the replacement telescope for the 300-foot in Green Bank. The idea of a large-aperture, fully steerable telescope is not new. It can be found in the original plan for the observatory when it was established in Green Bank. What was built was a smaller aperture, fully steerable telescope, the 140-foot, and a transit instrument, the 300-foot.

The idea of a 100-meter-class, fully steerable telescope was considered in both of the recent decade surveys in astronomy, the one for the seventies and the one for the eighties, and in both those surveys there is a report that indicates the importance of such a facility.

On the other hand, that telescope did not receive top priority—the VLA did in one case and the VLBA in another case—because we had working instruments in Green Bank. The telescopes, although 15 and then 25 years old, were working and productive.

Now, the collapse of the 300-foot telescope has removed a working instrument, of course, and it has given urgency to this planning. We have worked with the community, and our observatory staff has worked with the community, to develop the scientific case for a replacement telescope. We think that case is compelling.

There is a great deal of new research that can be done on pulsars, on mapping the structure of the universe, on studying star formation regions and our galaxy and other galaxies, in tracing the evolution of galaxies, in quasars, in studying the planets with planetary radar that would use both Arecibo Observatory and this new telescope. In studying the classic radiogalaxies in jets in VLB experiments, the telescope could be used in certain experiments with the new VLBA array.

We think that case is compelling, and we also have studied the technology and found that the technology of large telescopes has advanced. Much better reflector panel technology has been developed now so that panels can be manufactured at the same cost but higher performance than in past years, and if the surface figure is maintained by active control—that is, by a system of motorized supports for the panels—the high-frequency performance of the telescope can be much improved over what would have been possible years ago.

This scientific and technical case has been presented to the National Science Foundation, and they are now considering whether or not they want to make this part of their program.

There are other projects, of course, in radio and optical astronomy that I believe are important. You will hear about them, I am sure, from the other panelists, but very briefly, they are the upgrade of the Arecibo Observatory, the development of the millimeter interferometers in California, university facilities that will lead some day to a national millimeter facility known as the millimeter array, and, of course, the 8-meter telescopes for optical astronomy. But I will leave further remarks on those projects to the other panelists.

Thank you.

[The prepared statement of Dr. Vanden Bout follows:]

TESTIMONY TO THE HOUSE OF REPRESENTATIVES
SUB-COMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY

March 14, 1989

Paul A. Vanden Bout
Director
National Radio Astronomy Observatory

NSF ASTRONOMY PROGRAM

The opportunity to testify on the NSF research program in astronomy is welcome. Never have there been greater or more challenging opportunities for astronomical research. Never has the NSF astronomy program been in greater danger of collapse.

The Crisis in Operations Budgets

Let me begin with the first issue Chairman Walgren mentions in his letter of invitation: "We would like your views on the objectives of the proposed NSF research program in astronomy for fiscal year 1990, as well as your comments on the adequacy of support for astronomy by NSF in light of both the total national and international research effort in astronomy and also current research opportunities in astronomy."

In sharp contrast to the average rate of growth in the Foundations's budget of 10 percent annually since 1983, budgets for operation of the National Astronomy Centers have steadily declined. The 1990 budget, as proposed to Congress, is critically inadequate. Following five years of relentless budget cutting, the proposed 1990 budget will finally cripple the Centers and threaten their future existence.

I can speak best to the situation at NRAO. The fact is that the NRAO staff available to support the Observatory operations is the same today as it was in 1978. The budget is the same as it was a decade ago, accounting for inflation. What then is the difference? Our responsibilities have increased dramatically. The Very Large Array, the world's finest radio astronomy facility, was not even dedicated until 1980. Now it is one of the most sought after astronomical facilities in the world. It's success has been phenomenal. Nevertheless, ever tightening budgets have forced staff levels to lower and lower numbers. In every area we have uncompetitive staff compensation. Obvious maintenance needs have been deferred. Equipment purchases are absurdly low. At every site, staff morale is low and key people are leaving. One of the world's finest staffs in technical development is close to disbanding.

The recent NRAO budget history is shown in Figure 1, a graph of the actual funds received each year for operations since 1984. A line is also shown which indicates what those funds would have been if the 1984 budget had been increased each year to account for the modest rate of inflation in those years and no more, that is, no real budget growth. The Observatory has taken a roughly $4,000,000 cut, 25 percent of its present budget, with respect to its 1984 budget adjusted for inflation.

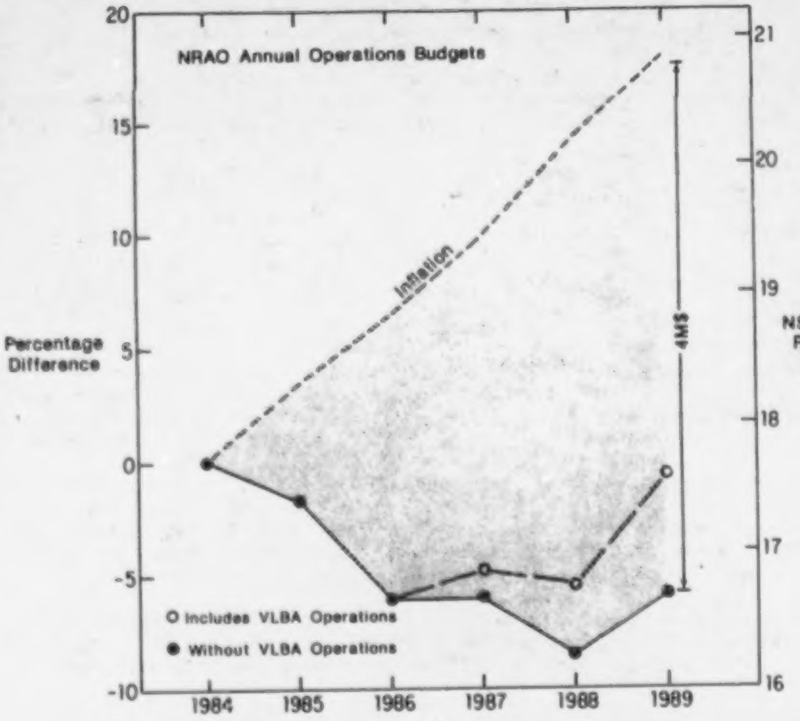

Fig. 1 Funds received from NSF for annual operations budgets are shown as solid dots, and including VLBA operations as open dots. The dashed line indicates the 1984 operations budget corrected for inflation.

The 1990 budget planned by NSF for NRAO in its request to Congress offers no relief but rather continues the destructive course of recent years. The following was recently presented to the National Science Board's Committee on Programs and Plans.

Summary of NRAO Budget Situation for the National Science Board Programs and Plans Committee

	1989 Actual as Reduced from Prior Plan	1990 as Planned to Meet Current Needs	1990 Near-Term Survival - Fallback
Base Operations	16.9	19.9	18.1
VLBA Operations	0.9	2.5	1.5
Equipment	0.0	1.2	0.7
VLBA Construction	11.8	12.5	12.0
	29.6	36.1	32.3
NSF 1990 Request to Congress		31.2	
Estimated NSF "Taxes"		-0.5	
Available at Request Level		30.7	Shortfall = 1.6M$

A reduction of about 10 percent in staff levels was forced upon us this past year by budget constraints. An additional shortfall of 1.6M$ would require a 20 percent cut in personnel or at least 40 employees. The Observatory cannot survive a cut of this magnitude without closing the Green Bank and eventually the Tucson sites.

Nineteen eighty-nine is the fifth year in a series of reduced budgets for base operations. The 1989 budget is slightly less in actual funds received than the budget of 1984, *but the 1989 budget must cover VLBA operations as well*.

NRAO has survived a 4M$ cut with respect to inflation since 1984 by reducing staff levels, cutting other expenses to the minimum, and transferring employees to VLBA and NASA construction projects. A total of 69 individuals are now supported by construction projects. The NASA project will be finished this year and VLBA will be finished in early 1992. Most of these 69 employees are needed for VLBA operations. But unless NSF provides full funding for operation of the VLBA, the Observatory faces an even more serious personnel crisis.

Declining budgets of the last several years have produced further critical needs that must be addressed: deferred major maintenance of the VLA track and electrical power systems accumulated; computing hardware and software needs; equipment for new instrumentation, technical development, and testing; inadequate graduate and postgraduate training programs.

Ultimately, the failure to address these needs will totally compromise the ability of the Observatory to function as a world-class institution. The consequences for individual university-based investigators, which make up NRAO's user community, will be catastrophic. Continued inadequate funding will also demoralize the already strained Observatory staff. If the core technical team disbands, the Observatory has no future.

Construction Budgets

Like budgets for operations, budgets for major construction projects are inadequate. The Very Long Baseline Array (VLBA), astronomy's current major construction project, has been funded by the difference between small increases in the NSF astronomy program's total budget and reduced budgets for existing programs and operations. Because there is a limit to the amount of money that can be produced this way without suddenly destroying existing programs, the annual funds available for construction are too small. This leads inevitably to stretched construction schedules and increased total project costs.

Forcing construction projects to be accommodated in a level total budget also leads inexorably to a day of reckoning when the new facility must assume full operation. Either the annual construction budget is transformed into an operations budget, cutting off all future construction projects, or existing operations budgets, already strained to the breaking point, must do the impossible and absorb the new operations. Because the VLBA can be brought into operation gradually as antennas are finished and outfitted, this crisis has announced its presence early, well before the end of construction in 1992. So far the solution imposed by NSF has been the latter alternative--squeeze existing operations still harder. Figure 2 shows NRAO's planned budget

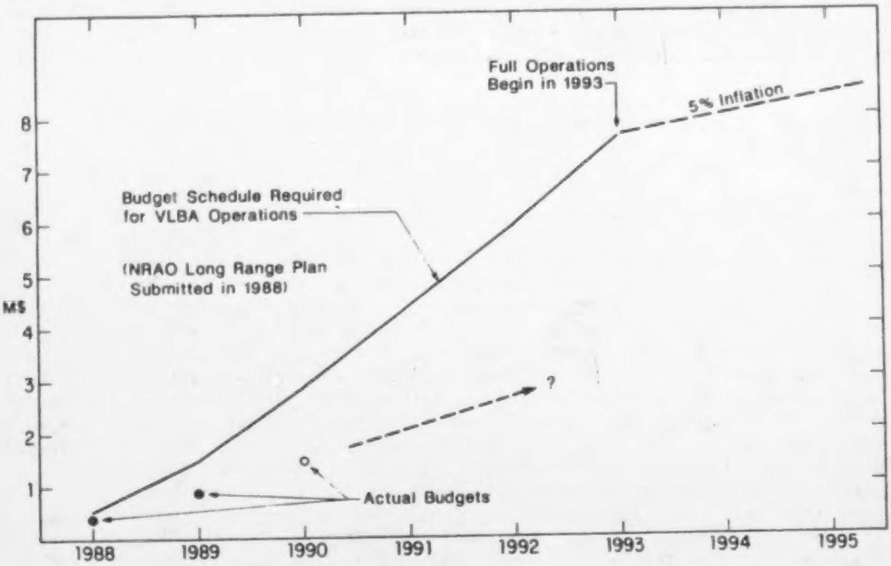

Fig. 2. The solid line shows the budget schedule required to bring the VLBA into operation as antennas are completed. Actual budgets are shown as solid dots for 1988 and 1989; an estimate for 1990 is shown as an open dot.

schedule for bringing the VLBA into operation. Actual budgets for 1988 and 1989, as well as an estimate for 1990, are shown. The shortfall is significant. If the trend continues, roughly half the VLBA antennas will be left idle by the end of construction for lack of operations funding.

Inadequacy of the NSF Astronomy Program With Respect to the Total National Program

At the same time NSF astronomy, the major part of federally-funded ground-based astronomy, is coping with declining budgets, NASA has announced plans for an impressive array of astronomy and astrophysics missions. The realization of even a fraction of these space plans will place major new demands on NSF's ground facilities. The Hubble Space Telescope alone will do this, and NASA hopes for two launches per year of astrophysics missions for the rest of the century.

The impact of space astrophysics missions on ground-based astronomy can easily be seen in the experience with the Infrared Astronomy Satellite (IRAS). This mission has profoundly influenced the course of research on NRAO telescopes. About 30-40 percent of all NRAO observing programs are now based on, inspired by, or related to IRAS results.

If left uncorrected, the weakened ability of NRAO and the other Centers to respond to this challenge will mean the space program results, although spectacular in themselves, will not be fully exploited for their scientific value.

Astronomy's Influence on Other Scientific Disciplines and Technology

Let me turn to the second issue raised by Chairman Walgren: "Of particular interest are your thoughts on ways that research in astronomy contribute to the advancement of other fields of science."

The strong coupling between astronomy and physics is obvious. Many practicing astronomers and astrophysicists were trained as physicists and regard astronomy as a branch of physics. I believe the direct influence of astronomy on physics lies in the fact that astronomy provides physics with examples of physical systems that do not exist in the laboratory. The stars are the only examples of sustained nuclear fusion processes. The binary pulsar 1937+21 provides the only empirical evidence for the existence of gravitational waves. Einstein's theory of general relativity meets its most stringent tests in astronomical phenomena. The history of the early universe is inextricably coupled to the nature of elementary particles proposed by theory and searched by experiment in accelerators. Observations of neutrinos from supernova 1987a set limits to the mass of the neutrino. These examples are merely indicative, certainly not exhaustive, of the linkage between astronomy and physics.

Astronomical discovery has provided impetus in chemistry as well. Only in interstellar space is matter so rarified that highly reactive molecules, ions, and radicals can exist for long periods of time. The discovery of these molecular species in the interstellar matter of the Galaxy in the 1970's stimulated the development of an entire new field of chemistry--astrochemistry--to account for the formation and reaction networks under space conditions of these molecules. Laboratory spectroscopy of highly reactive molecules was also given impetus.

Astronomical research has a long record of creating new technology. Attachment A is an account prepared in 1987 of the technology developments fostered by radio astronomy It is an impressive list of contributions to the fields of microwave receiving systems, data correlation and recording technology, image restoration software, time and frequency standards, and remote sensing, navigation, and geodesy. More recently, the performance of NRAO-developed microwave amplifiers have attracted the attention of the National Security Agency.

Plans for New Facilities in Radio Astronomy

Finally, let me address the last of the issues highlighted by Chairman Walgren: "Your views on priorities for new astronomical research facilities would be welcome. In particular, what priority should be assigned to replacing the capabilities lost by the recent collapse of the radio telescope at Green Bank?"

Prior to the collapse of the 300-foot telescope, NRAO's plans for the major new facilities were centered on the Millimeter Array, an array telescope patterned after the Very Large Array but operating at millimeter wavelengths. At the same time a study was going on of a possible replacement for the aging Green Bank telescopes. The loss of the 300-foot telescope gave urgency to the latter study.

Following the collapse of the 300-foot telescope on November 15, 1988, the Observatory staff and user community worked to define the scientific requirements and technical specifications of a replacement telescope. It is clear that there is a compelling scientific case for a fully steerable, high performance, large aperture radio telescope and that new technology makes it possible to build such a telescope at reasonable cost that is superior to any existing steerable antenna. The estimated budget for the entire project is 75M$ (1989). The telescope will begin operations in late 1994/early 1995.

The scientific program for the telescope and the implied technical requirements were discussed in a workshop held in Green Bank, December 2-3, 1988, and subsequently refined by the Observatory staff (A Radio Telescope for the Twenty-First Century--Scientific Considerations for the Design of a Replacement for the 300-Foot Radio Telescope). The telescope will make major contributions to the study of the structure of the universe, the gaseous content of galaxies, solar/stellar phenomena, molecular clouds and star formation, evolution of galaxies, the solar system, the nature of radio galaxies and quasars, fundamental catalogs, as well as applications to space VLBI. Despite the diversity of scientific needs, a telescope design has been specified which offers major technological advances over existing instruments to every relevant area of research.

At longer wavelengths the new telescope will have more effective collecting area compared with the 300-foot telescope, as well as full steerability and access to the galactic center. At shorter wavelengths the sensitivity of the new telescope will exceed by a substantial margin that of any other fully steerable telescope in the world, including the Max-Planck-Institut fur Radioastronomie 100-meter telescope in Effelsberg, Germany. At wavelengths of a few millimeters the telescope could exceed the performance of the Nobeyama Observatory 45-meter telescope if dynamic control of the panel setting can be achieved.

The technical issues and tradeoffs in the design of the new telescope were studied by a group of NRAO engineers and scientists. Their major finding is that the cost of the telescope is only weakly dependent on the high-frequency operational limit. Refinements in panel manufacturing techniques allow for the routine assembly of panels with a root-mean-square surface accuracy of about 70 micrometers, so that the performance of the new telescope at short wavelengths is dependent on the setting of the panels and compensation for gravitational, thermal, and wind deformations of the support structure. By supporting the panels on motorized adjusters and controlling the setting according to a pre-determined look-up table, the gravitational deflections can be cancelled so that the surface root-mean-square is $\lambda/16$ at $\lambda = 7$ mm or better. Further refinement of the look-up table and the addition of compensation for thermally induced deformations will eventually allow operation at shorter wavelengths, perhaps to 2.6 mm.

Their report also discusses pointing considerations and methods for reducing aperture blockage. All of the options provide improvements on existing telescopes and increased protection from interfering signals--natural and man-made. The best-performance option, a totally unblocked aperture, requires detailed structural analysis to evaluate its feasibility. An unblocked design costs more for a given diameter than a conventional axisymmetric design. A decision to build an unblocked design for the cost estimate given below would imply a telescope of less than 100-m but more than 70-m diameter.

Green Bank, West Virginia, is the obvious choice of site for the new telescope. A substantial infrastructure already exists in Green Bank, together with a skilled staff that has many years of experience in single dish radio astronomy. The fact that Green Bank is in the National Radio Quiet Zone and enjoys protection from certain forms of radio interference is a major consideration. The NRQZ, plus minimization of blockage in the new telescope, will make this facility the most powerful in the world for projects sensitive to interference. For VLBI applications the east coast location complements the large collecting area available with the VLA in the southwest and the 100-m Effelsberg antenna in Europe. Finally, the site is acceptable for observing at several millimeters wavelength. Analysis of radiosonde data (F. R. Schwab, "Analysis of Radiosonde Data from Huntington WV, Pittsburgh PA, and Albany NY," NLSRT Memorandum No. 52, NRAO) shows Green Bank to be equivalent to the Five College Radio Astronomy Observatory site, in Massachusetts, where there are years of experience in millimeter wavelength observing.

There are other construction projects in radio astronomy, all relatively small compared with construction of a major new facility. The upgrade of the Arecibo Observatory is one. It is a modification of the feed optics and receiver feeds together with installation of protection against ground radiation that would greatly increase the sensitivity of the telescope. NASA has offered to pay roughly half of the 22M$ cost if NSF will proceed with the project. It is important to do so, especially if a new telescope is built in Green Bank. The Arecibo and 300-foot telescopes were both used for many observing programs; Arecibo providing greater sensitivity for a limited part of the sky and the 300-foot greater sky coverage at reduced sensitivity. Building the new Green Bank telescope calls for a concomitant increase in the power and flexibility of the sister instrument in Arecibo to preserve the balance in capability.

At short wavelengths of 1.3-3 mm the pioneering U.S. facilities are interferometers. NSF funds the construction and operation of two, both in California, at the Hat Creek (UC, Berkeley) and Owens Valley (Caltech) observatories. These complementary facilities are the prototypes for the Millimeter Array and the results from these interferometers form much of the impetus for building the Millimeter Array. It is important that this work be supported for the sake of the science and to ensure that this area continues to develop, so that techniques, trained personnel, and scientific strategies are in place in the mid-1990's when a serious effort on the Millimeter Array could begin.

Balance in the Radio Astronomy Community

I will end with some brief remarks on an issue that has received attention from time to time. "Is the balance among the various elements of the NSF astronomy program appropriate?" I will focus on radio astronomy, but the remarks are generally applicable to optical astronomy as well.

U. S. radio astronomy, which is essentially supported only by NSF, rests on a tripod of institutional activities: the National Centers, NRAO and NAIC; the university observatories and major university research groups; and the individual investigators, both with and without grant support from NSF. All are essential elements of the entire program. The balance between these elements has evolved with experience accumulated over many years. The resulting combination has been cost-effective and scientifically productive.

Each element provides something unique on which the program depends. The centers provide large facilities which go well beyond what can be done with university-scale telescopes. The university observatories provide smaller-scale facilities that are often the prototypes of future national facilities and are the training ground for future instrument builders. Everyone does the science, but by far the bulk of it is accomplished by individual university-based investigators.

The role of NRAO is illustrative and presented in somewhat more detail in Attachment B, "A Profile of the NRAO." Over 761 users from 173 institutions, including 121 students, used NRAO telescopes in 1988. The NRAO staff used 10 percent of the observing time for which they competed on an equal basis (proposals reviewed by anonymous referees) with all users.

The National Centers play a critical role in providing observing facilities for young people establishing their careers. More often than not, they have no grant support. If they compete successfully for time on NRAO telescopes, they also receive assistance for travel to the telescope and for data reduction and support with page charge expenses when they publish their results. Failure to support this group of users would have profoundly serious consequences for the future of astronomy.

Summary

The interest of the Subcommittee in the adequacy of funding for the NSF astronomy program is timely in that the 1990 budget situation is critical. All budgets, both for the National Centers and for the Research Grants Program, are seriously inadequate. Prompt attention and corrective action is required to prevent crippling damage to the current activities and facilities under construction. Scientific challenges abound in astronomy and call for the timely construction of new facilities, both in radio and optical astronomy.

Attachment A

TECHNOLOGICAL DEVELOPMENTS FOSTERED BY RADIO ASTRONOMY

National Radio Astronomy Observatory

April 1987

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OVERVIEW

Radio astronomy is a science that is driven by the pace of technological improvements to its research instrumentation. Although the pioneering work in radio astronomy was conducted prior to 1940, the infant science did not fully blossom until after World War II. Major advances in the science came in the post-war era primarily due to the availability of the superb radar instrumentation developed during the war and also because of the interest of brilliant technologists who had excelled as radar and radio engineers driven by the war effort. It was clearly evident then, as it is today, that in order for a radio astronomer to work at the forefront of the discipline, his instruments needed to be at the forefront of the associated technology.

The communications industry has instrumental needs that are in many respects similar to those of radio astronomy, with the major exception that radio astronomers have no control over the natural radio signal transmitters that they struggle to detect. Consequently, radio astronomers have always been forced to develop antennas of the highest gain, receivers of the highest sensitivity, and in general instrumentation that defines the state of the art in signal reception and analysis. In many cases the required instrumentation was not available in other scientific disciplines or in industry and had to be developed specifically for radio astronomy. Oftentimes non-radio astronomy applications were discovered later. In other cases, a more symbiotic relation between the needs of radio astronomy and those of other sciences or of industry led to the development of instrumentation of value for each discipline. However, in all these circumstances the technical requirements of radio astronomy have directly or indirectly fostered technological innovations of wide applicability.

Engineering and software developments done principally for radio astronomy have contributed most to the five specific areas of technology that are described below:

- Sensitive microwave receiving systems, including
    - high gain antennas
    - low noise receivers
    - solid state oscillators and frequency multipliers
    - cryogenics

- Data correlation and recording technology

- Image restoration techniques

- Time and frequency standards

- Remote sensing, navigation, and geodesy

I. SENSITIVE MICROWAVE RECEIVING SYSTEMS

A. High Gain Antennas

Radio astronomers design and build antennas of the largest possible size and quality because celestial signals are extremely weak. This requirement has led to several major new technological developments that are just beginning to find commercial applications.

Homology Principle

One of the major limitations to the construction of large steerable antennas with precise reflecting surfaces is the gravitational deformations that change as the antenna is moved from one sky position to another. In 1967, S. von Hoerner published his Homology Principle in a paper addressed to astronomers[1] and in another to structural engineers[2]. An antenna with a design that incorporates homology will deform under changing gravitational stress--but it will deform into another paraboloid, albeit one with a different focal position and focal length. By tracking the focus the effect of the gravitational deflection is minimized and very large, accurate antennas are possible. In the strictest sense only radio telescopes have made full use of the homology principle, but nowadays all designs of large reflector antennas take advantage of homology at least to some degree. As the commercial antenna industry moves to ever higher frequencies, homology will become even more important. The Very Long Baseline Array (VLBA) antennas are examples of a modern design that has replaced an old 25-m antenna design providing a factor of four improvement in rigidity.

Holographic Antenna Metrology

Until recently the only techniques available for verifying the surface accuracy of an antenna were mechanical. Although radio astronomers helped develop these mechanical techniques, their greatest contribution to antenna metrology is the recent development of an electrical technique. This so-called "holographic method" uses the Fourier Transform relationship between the aperture illumination and the diffraction pattern of an antenna. Scott and Ryle[3] first used this technique to evaluate the antennas of the Cambridge 5-km array, following a suggestion of R. Hills. Bennett et al.[4] were the first to publish a discussion of the technique. The University of California, Berkeley radio astronomy group were the first to reset the surface panels of an antenna using this technique. It has been applied to the evaluation of virtually all major radio telescopes, and it is now part of the routine test and acceptance program of most new telescopes.

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[1] S. von Hoerner, "Design of Large Steerable Antennas," Astron. J., vol. 72, p. 35, 1967.

[2] S. von Hoerner, "Homologous Deformations of Tiltable Telescopes," Proc. ASCE - J. Struc. Div., vol. 93, p. 461, 1976.

Holography is a valuable new method for measuring the amplitude and phase of the electric field in the aperture of an antenna and, as antenna standards are tightened, the antenna industry is expected to make increasing use of this technique. Two firms evaluate antennas holographically as a commercial service: a group in Sheffield, England, and Interferometrics, Inc., of Vienna, Virginia. NASA has adopted the technique as the standard for evaluating the quality of the antennas used in the Deep Space Network.

Correcting Subreflectors

An improved knowledge of the irregularities of the primary reflector has suggested methods for their compensation. In 1976, S. von Hoerner[5] published a procedure to correct for such errors by constructing a subreflector with compensating errors. Most radio telescopes employ multiple reflecting surfaces to bring radiation to the receiver system and Von Hoerner's idea was to improve telescope performance by dealing with a small subreflector rather than the large primary surface. The first application was the deformable subreflector on the NRAO 140-ft telescope which compensated for gravitational deflection of the primary surface by bending the subreflector.[6] More recent applications have fabricated optics to correct for specific surface errors revealed by holographically produced maps. The

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[3] P. F. Scott and M. Ryle, "A Rapid Method for Measuring the Figure of a Radio Telescope Reflector," Mon. Not. Roy. Astr. Soc., vol. 178, p. 539, 1977.

[4] J. C. Bennett, A. P. Anderson,. P. A. McInnes, A. J. T. Whitaker, "Microwave Holographic Metrology of Large Reflector Antennas," IEEE Trans. Ant. & Prop., vol. AP-24, p. 295, 1976.

[5] S. von Hoerner, "The Design of Correcting Secondary Reflectors," IEEE Trans. Ant. & Prop., vol. AP-24, p. 336, 1976.

[6] S. von Hoerner and W-Y. Wong, "Improved Efficiency with a Mechanically Deformable Subreflector," IEEE Trans. Ant. & Prop., vol. AP-27, p. 720, 1979.

California, Berkeley radio astronomy group recently reported improvements to one of their millimeter-wave telescopes by use of an error-correcting lens.[7] The University of Texas millimeter astronomy group has made dramatic improvements in the high-frequency performance of their 5-m telescope with error-correcting mirrors.[8,9] High performance telescopes of the future may well incorporate error-correcting optics as a standard technique for meeting specifications.

High Efficiency Antenna Feeds

In the 1960's, driven by the needs of radio astronomy, engineers and astronomers in the U.S. and Australia independently developed feeds which efficiently illuminate the main reflector. These circular-aperture hybrid-mode corrugated feed horns are widely used now in the communications industry and are essential to the operation of communications satellites. The history of this development has been documented recently by Thomas[10]. These horns are manufactured by many companies, including Rantec, Inc., TIW, and ERA Technologies, Ltd.

B. Low-Noise Receivers

Masers

Maser amplifiers were first used in the 1950's by the communications industry and radio astronomers for the reception of weak signals. Early communication satellites transmitted at a comparatively low power level due to the scarcity of on-board electrical power. (This is less of a problem these days since the advent of higher performance solar cells.) The interchange between techniques developed for radio astronomy equipment and for military/commercial equipment was especially true in the area of maser development. Following the pioneering work of Townes at Columbia University and others, AIL (Airborne Instruments Laboratory) built a number of maser systems for a wide range of applications. Each one advanced the understanding of this new technique; none were simply copies of previous units. Radio astronomy instrumentation was as much of a motivating factor as the pressure for improved satellite communications. Maser systems installed on the Parkes Radio Observatory antenna in Australia received data from the Giotto satellite during its closest approach with Comet Halley[11]. Although maser amplifiers have been largely superseded at lower frequencies, development is being continued by NASA/JPL for reception of weak signals from deep space probes and also by the radio astronomy community for use in the 20-50 GHz frequency range.

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[7] J. Hudson, abstract, URSI (National Radio Science Meeting), June 1985 Vancouver meeting.

[8] H. Foltz, "Dual Subreflector Feeds," Technical Report No. 85-3, Elec. Engr. Res. Lab., Univ. of Texas at Austin, 1985.

[9] C. E. Mayer, "Texas 5-m Antenna Efficiency Doubled at 230-290 GHz with Error Correcting Secondary Optics," abstract, URSI (National Radio Science Meeting), January 1986 Boulder meeting.

[10] B. MacA. Thomas, "A Review of the Early Developments of Circular-Aperture Hybrid-Mode Corrugated Horns," IEEE Trans. Ant. & Prop., vol. AP-34, p. 930, 1986.

Parametric Amplifiers

Strongly supported by radio astronomy, companies like AIL (Airborne Instruments Laboratory) developed parametric amplifiers in the late 1950's. Specifically, the radio astronomy community provided a major part of the driving force for higher sensitivity and wider bandwidth at higher frequencies. The satellite communications industry, both commercial and military, benefited in the 1960's and 1970's from this earlier work. In fact, a series of companies were formed on Long Island about this time to meet this need for high performance satellite communication systems. The entrepreneurs who started some of these companies (LNR, Comtech, etc.) had been actually involved at the bench level in building parametric amplifiers for the radio astronomy community.

GaAs FET

The push to develop GaAs FET (gallium-arsenide field effect-transistor) amplifiers came largely from the communications industry. These have replaced parametric amplifiers as the most commonly used low-noise amplifier for the reception of satellite transmissions. However, the radio astronomy community (NRAO and the University of California - Berkeley) have pioneered the development of cryogenically-cooled GaAs FET amplifiers for high sensitivity receiving systems. Berkshire Technologies was formed by former radio astronomers to meet NASA and industry requirements for cryogenic GaAs FETs.

HEMT

HEMT's (high-electron-mobility transistors) are recently developed semiconductor devices that have already found their way into both the computer and communication fields. Again, the radio astronomy community

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[11] R. Reinhard, "The Giotto Encounter with Comet Halley," Nature, vol. 321, p. 313, 1986.

(NRAO) with help from NASA (JPL) has supported the development of HEMT devices by GE and Cornell University for use in cryogenically-cooled amplifiers. Since these developments are relatively recent, the full impact is not clear yet; however, the NASA/JPL DSN (Deep Space Network) is evaluating the use of these amplifiers to replace masers which are difficult to maintain in the field. There are also early indications that there is interest by a company involved in defense work in a technology transfer from NRAO. These amplifiers are currently being installed on the Very Large Array (VLA) in order to obtain higher sensitivity for the reception of signals from Voyager II during the Neptune encounter during August 1989.

Schottky Mixers

Cooling reduces the noise of solid-state amplifiers. Weinreb and Kerr[12] pioneered the application of cryogenic cooling of GaAs Schottky mixers in order to improve their performance for radio astronomy. Although the cooling of mixers has not found wide commercial use, the engineering that has gone into the fabrication of cooled mixers has. The IEEE papers of Kerr and Archer have attracted world-wide interest from commercial and defense organizations. Kerr and Held were awarded the IEEE Microwave Prize for their papers covering conversion-loss and noise of microwave and millimeter-wave mixers[13,14]. Millitech was formed by a few talented radio astronomers and is now a major support firm for millimeter and submillimeter wave technology. The success of this company comes from having the right background at a time when the defense industry needs moved up into the millimeter range (battlefield radar systems, etc.).

Superconducting-Insulating-Superconducting (SIS) Mixers

Most major radio astronomy observatories making millimeter-wave observations are currently developing SIS mixers for low-noise receivers. Several observatories are successfully using these devices in receivers. Despite the few years that these devices have been in use, there is already a technology interchange in progress between NRAO and several commercial and government organizations (Hypress, NRL, NSA, etc.).

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[12] S. Weinreb and A. R. Kerr, "Cryogenic Cooling of Mixers for Millimeter and Centimeter Wavelengths," IEEE Journal of Solid-State Circuits, vol. SC-8, February 1983.

[13] A. R. Kerr and D. Held, "Conversion-Loss and Noise of Microwave and Millimeter-Wave Mixers: I - Theory," IEEE Trans. on Microwave Theory and Tech., vol. MTT-26, p. 49, 1978.

[14] A. R. Kerr and D. Held, "Conversion-Loss and Noise of Microwave and Millimeter-Wave Mixers: II - Experiment," IEEE Trans. on Microwave Theory and Tech., vol. MTT-26, p. 55, 1978.

Solid-State Oscillators and Multipliers

Phase-locked, millimeter-wave sources for use as broadly tunable local oscillators for radio astronomy are not readily available commercially. Consequently, the radio astronomy community has made substantial progress in the development of varactor multipliers[15] (Archer) and voltage-tunable Gunn oscillators[16] (Carlstrom, Plambeck, and Thornton). There has been considerable commercial interest in these devices and follow-up work at Millitech Inc. has led to their successful marketing.

Cryogenics

The low-noise amplifiers used on radio astronomy antennas are generally operated at cryogenic temperatures - 15K or 4K are commonly used. The closed-cycle refrigerators used are usually Gifford-McMahon refrigerators built by CTI (Cryogenics Technology, Inc.). The 4K system uses the same refrigerator type with an add-on Joule-Thompson circuit. Reliability of these cryogenic systems has always been important to the radio astronomy community, and radio engineers have worked closely with the manufacturer (CTI) to improve system performance and reliability. Some improvements to the compressors that were developed and evaluated by NRAO have been incorporated by the manufacturer. These systems have also had beneficial use in the semiconductor industry as the central component of low temperature vacuum pumping units.

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[15] J. W. Archer, "An Efficient 200-290 GHz Frequency Tripler Incorporating a Novel Stripline Structure," IEEE Trans. on Microwave Theory and Tech., vol. 32, p. 416, 1984.

[16] J. E. Carlstrom, R. L. Plambeck, and D. D. Thornton, "A Continuously Tunable 65-115 GHz Gunn Oscillator," IEEE Trans. on Microwave Theory and Tech., vol. MTT-33, p. 610, 1985.

II. DATA CORRELATION AND RECORDING TECHNOLOGY

A. Digital Correlation Techniques for Spectral Analysis of Broadband Signals

Many radio astronomical observations involve the spectral analysis of a broadband signal, the most common example being observations of an atomic or molecular spectral line. The frequency bandwidths that the astronomer needs to analyze, 10-1000 MHz, are extremely large for traditional techniques such as analog filters. Instead, radio astronomers have developed digital techniques involving coarse quantization (1-3 bits) and autocorrelation of wideband signals. The advantages of digital correlation are greater flexibility, reliability, and stability, with inexpensive components. The seminal work on digital techniques for spectral analysis in radio astronomy is that done by Weinreb[17] and Cooper[18].

Digital correlation is now used extensively in remote sensing applications (from earth satellites), oceanography, and oil exploration.

A contemporary digital spectrometer which provides the flexibility needed in radio astronomy to analyze signals of vastly different bandwidths (from 1.25 to 320 MHz) is described by W. Urry et al.[19]

Digital techniques employing coarsely quantized data also permit one to cross-correlate data rapidly from many separate signals. For example, the VLA radio telescope requires data to be correlated at a rate of $2x10^{12}$ multiplications per second. If this was to be performed with floating point numbers in a large computer then the power of 100 CRAY supercomputers would be needed. However, by using 3-level arithmetic, a special purpose digital correlator was built for this task at a cost of only 2 million dollars.

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[17] S. Weinreb, "A Digital Spectral Analysis Technique and Its Application to Radio Astronomy," M.I.T. Research Laboratory of Electronics, Tech. Report 412, 1963.

[18] B.F.C. Cooper, "Autocorrelation Spectrometers," Methods of Experimental Physics, vol. 12B, p. 280, 1976.

[19] W. L. Urry, D. D. Thornton, and J. A. Hudson, "Hat Creek Millimeter-wave Hybrid Spectrometer for Interferometry," Publ. Astron. Soc. Pacific, vol. 97, p. 745, 1985.

B. Wideband Tape Recording

The radio astronomical technique of Very Long Baseline Interferometry (VLBI) requires very wideband tape recording. Simultaneous observations are made at radio telescopes separated by tens to thousands of miles, and the tape recorded data are played back and cross-correlated at a latter time at a common location. Initially, radio astronomers used video cassette recorders, readily available in the consumer market at low cost, to record digital data. In addition, instrumentation recorders have been improved by more than an order of magnitude for high VLBI data rates. VLBI observations are recorded at a density of one million bits of information on each square inch of instrumentation tape.[20] The technique for doing so has attracted commercial interest.

C. Archival Mass Storage

The enormous data storage requirements of radio astronomical observations made conventional magnetic storage techniques uneconomical. To meet these requirements, astronomers have developed low-cost instrumentation recorders by using analog recorders to record digital data. One system in operation uses a Video Cassette Recorder for this purpose.

The NRAO has investigated whether the performance of these devices could be improved so that they might also be employed to store archive data. In the process of investigating the feasibility of using such a recorder for VLA archive data, the NRAO developed a prototype recorder suitable for high performance recording.

The new recorder resembles a streaming magnetic tape drive. It has a capacity of 2.5 gigabytes of user data and a data rate of 120 kilobytes per second. It employs read after write, error correction circuitry, and spatial multiplexing to achieve a rate low enough for high-performance recording.

The ability to place 2.5 gigabytes of data on a $4 cassette tape in an essentially error-free environment makes such a recorder very attractive for a number of fields. Disk backup, archiving of both scientific and business data, and medical electronics are but a few.

Ray Escoffier, the inventor and an AUI employee, has applied to patent the recording system and to provide for a life-long royalty free license to the United States Government. The first patent (Serial No.

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[20] K. I. Kellermann and A. R. Thompson, "The Very Long Baseline Array, Science, vol. 229, p. 123, 1985.

870,305) is currently pending. Digi Data, an OEM manufacturer of magnetic tape equipment located in Maryland, has been licensed to manufacture the recorder. The company has further developed the recorder, taking it from a demonstration of feasibility to a marketed product in late 1986.

III. IMAGE RESTORATION ALGORITHMS

A. Aperture Synthesis Techniques

The angular resolution of a radio telescope is proportional to the diameter of the dish antennas measured in wavelengths. Larger telescopes can more easily see fine scale details in cosmic sources. But, there is a limit to the size of an individual telescope that one can construct. To achieve still higher angular resolution, it is possible to synthesize a single telescope from an array of spatially separate antennas which simultaneously observe a position in the sky. The basic technique of aperture synthesis samples an electromagnetic wave front at many widely separated locations and then uses the Fourier transform of these data to stimulate the response that would have been obtained with a much larger, single antenna. The radio astronomer Sir Martin Ryle received the Nobel Prize in Physics for the conception and demonstration of this technique.

The principles of the aperture synthesis technique are directly incorporated in many non-astronomical image construction endeavors which are widely available commercially, such as the following,

- synthetic aperture radar
- X-ray tomography of human tissue.[21]

B. Self-Calibration Algorithms: Adaptive Optics

Distortion of an image by the atmosphere is a problem common to both radio and optical telescopes. This problem restricts synthesis array radio telescopes such as the VLA. The distortion manifests itself through collimation errors resulting from spatially and temporally varying refractivity of the atmosphere above the array. Years ago the radio astronomer Roger Jennison derived phase closure mathematical relations that could be applied to observations with telescope arrays in order to circumvent these effects and sharpen the radio images.[22] This technique, suitably refined and known as self-calibration, is now routinely employed in radio astronomy.[23]

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[21] R. N. Bracewell and A. C. Riddle, Ap. J., 150, 427, 1967.

[22] R. C. Jennison, "Fourier Transforms of Spatial Brightness Distributions of Small Angular Extent," Mon. Not. Roy. Astr. Soc., vol. 118, p. 276, 1958.

[23] F. R. Schwab, "Adaptive Calibration of Radio Interferometer Data," Proc. Soc. of Photo-Optical Instrumentation Engrs., vol. 231, p. 18, 1980.

To an optical telescope, the effect of the atmosphere is easily seen in, for example, the twinkling of stars. Atmospheric turbulence generates an irregular distortion of the wavefront across the telescope aperture. If it were possible to distort the shape of the telescope mirror in the same way, then one could cancel the atmospheric distortion and sharpen the image. This is precisely what is done. With an articulating mirror driven by pistons, the shape of the mirror is continuously deformed in real-time until the image sharpens. Such a technique for optical telescopes is called "adaptive optics," but it is in all ways analogous to the radio astronomical technique of self-calibration. Adaptive optics is also used in satellite cameras to improve their photographic capabilities.[24]

C. Maximum Entropy Algorithm

Synthesis array telescopes do not fully sample the incoming electromagnetic wavefront, and it is necessary to interpolate from the measured points so as to fill in the "missing" data. Such image processing by means of the maximum entropy algorithm, a technique first developed for the analysis of seismic data, has been greatly refined for application to radio astronomical problems.[25]

So successful has been this improvement that the astronomical software algorithms developed by radio astronomers are now used for problems of blurred photographic images in non-astronomical contexts (e.g., sharpening images for police work). Several commercial firms now market the maximum entropy algorithms for diverse applications. Maximum Entropy Data Consultants Ltd. is one such firm.

D. Astronomical Image Processing Systems (AIPS)

AIPS is an extensive integrated software package for manipulation of multi-dimensional images. Developed by the NRAO, AIPS is distributed without charge for use by hundreds of scientists worldwide. Designed to be machine independent, it runs on all classes and makes of computers, from minicomputers to supercomputers; it is routinely used in nonastronomical image analysis applications. Several hardware vendors advertise and promote the suitability of their equipment for AIPS support. Among these are the following:

CONVEX Computer Corporation, Inc.
International Imaging Systems, Inc.

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[24] R. Muller and A. Buffington, "Real-time Correction of Atmospherically Degraded Telescope Images Through Image Sharpening," J. Optical Soc. of America, vol. 64, p. 1200, 1974.

[25] S. Gull and G. Daniell, "Image Reconstruction from Incomplete and Noisy Data," Nature, vol. 272, p. 686, 1978.

IV. TIME AND FREQUENCY STANDARDS

A. Hydrogen Maser Frequency Standard

The technique of Very Long Baseline Interferometry (VLBI), in which tape-recorded data taken by telescopes thousands of miles apart are brought together and cross correlated, requires that each telescope maintain exceptional frequency stability. Specifically, the frequency at each station must be stable to better than one part in 10^{14} over a period of several hours. At the present time only active hydrogen masers can provide the required stability.[26]

Hydrogen masers, which produce the 1420-MHz hyperfine transition of atomic hydrogen as their fundamental output, were developed as an experimental time standard by the NBS. Prior to the needs of VLBI, there was no commercial maker for this laboratory device. Reliable field-ready hydrogen masers were subsequently developed by the Smithsonian Astrophysical Observatory and at NASA/Johns Hopkins Applied Physics Laboratory in order to supply each individual VLBI antenna with its own hydrogen maser frequency standard. These designs have been developed into a commercial product by Oscilloquartz S. A. in Switzerland and Sigma Tau Standards Corporation in Alabama, among others. The present market for hydrogen maser frequency standards is dominated by space communications and DOD needs. Finally, Hughes Research Laboratories is developing a space-qualified hydrogen maser for use on the NAVSTAR Global Positioning Satellites.

B. Time Standards and Time Transfer

A standard of time may have more than one appropriate definition. For a laboratory experiment a suitable time standard may be an atomic clock. For an astronomical observation, on the other hand, or a determination of the position (orbit) of an earth satellite "time" refers to the rotation of the earth on its axis. This rotation is not constant. Not all earth days are of the same duration owing to subtle wobbles of rotation of the earth.

The USNO relies heavily on the radio astronomical data for their daily determination of the earth's rotation periods. Using a worldwide network of optical telescopes augmented in an important way by radio astronomical observations with the NRAO interferometer in Green Bank, WV, the USNO constantly monitors the rotation of the earth relative to an astrometric grid of very constant radio sources (quasars). Unlike the optical determinations, the radio astronomical observations can be made day and night, and they are affected by clouds or the weather to a relatively small degree. The USNO radio technique and its application is discussed by Winkler[27] and Matsakis *et al.*[28]

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[26] A. Rogers and J. Moran, "Coherence Limits for Very Long Baseline Interferometry," IEEE Trans. on Instru. and Measur., vol. IM-30, p. 283, 1981.

In order to transfer a single laboratory reference time to distant clocks with high accuracy, one must develop a synchronization method. The VLBI technique is routinely used in radio astronomy to synchronize telescope clocks to nanosecond accuracy worldwide. This method also has applications for very precise navigation and in other non-astronomical contexts.

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[27] G. Winkler, "Time Keeping and Its Applications," *Advances in Elect. and Electron Phys.*, vol. 44, p. 33, 1977.

[28] D. Matsakis *et al.* "The Green Bank Interferometer as a Tool for the Measurement of Earth Orientation Parameters," *Astron. J.*, vol. 91, p. 1463, 1986.

V. REMOTE SENSING, NAVIGATION, AND GEODESY

A. Microwave Thermography of the Human Body

Observations of cosmic sources of radio radiation made with a radio telescope are fundamentally measurements of the temperature of those objects. Instead of looking at the sky, one can use the same technique to scan the human body and, in so doing, measure precisely the distribution of temperature across the body. Since malignant tumors and regions of vascular insufficiency are thermally anomalous, these features are readily apparent on microwave scans of the human body.

Radio astronomers have adapted this technique for non-invasive measurement of the temperature of subcutaneous human tissue.[29] Although microwave radiometry has coarser spatial resolution than infrared thermography, it has a greater sensitivity to deep tissue temperature. Flesh is transparent at microwave frequencies. Clinically, in application to the detection of breast cancer, the combination of microwave and infrared thermographic data provides a true-positive detection rate of 96 percent.[30] Microwave thermography does not expose patients to harmful radiation.

B. Atmospheric Ozone Monitoring

The depletion of the protective layer of ozone (O_3) in the stratosphere is a matter of utmost current concern since potentially increased levels of solar UV radiation on the surface of the earth will result from a diminished O_3 concentration. For several years scientists have known that chlorine monoxide ($C\ell O$) is a key tracer of the stratospheric ozone depletion cycle arising from natural and man-made injection of chlorine-containing compounds, particularly halocarbons, into the atmosphere. The reactions

$$O_3 + C\ell \rightarrow C\ell O + O_2$$
$$C\ell O - O \rightarrow C\ell + O_2$$

constitute the catalytic cycle by which chlorine atoms convert ozone to diatomic oxygen.

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[29] A. H. Barrett and P. Myers, "Subcutaneous Temperatures: A Method of Noninvasive Sensing," Science, vol. 190, p. 669, 1975.

[30] A. H. Barrett, P. C. Myers, and N. L. Sadowsky, "Microwave Thermography of Normal and Cancerous Breast Tissue," Proc. 3rd Intern. Symp. on Detection and Prevention of Cancer (Decker: New York), 1978.

Radio telescopes can directly measure and monitor the stratospheric abundance of CℓO, and its diurnal and long-term variation. Radio astronomers demonstrated the efficacy of this technique by means of observations of the J = 11/2 - 9/2 and J = 15/2 - 13/2 rotational transitions of CℓO at 204 and 278 GHz, respectively. Such ground-based observations provide a cost-effective way of monitoring potential damage to the ozone layer using existing radio astronomical instruments and techniques.[31]

C. Remote Sensing Satellites

One of the most economically significant applications of radio astronomy techniques has been to remote sensing satellites which carry passive imaging microwave spectrometers operating at wavelengths ranging from several centimeters to a few millimeters. Early successes in mapping atmospheric temperature and humidity fields, polar ice distributions, and other geophysical parameters, even in the presence of clouds, have led to the steady use of passive microwave temperature sounders on the operational NOAA and DOD weather satellites, and the anticipated primary use of a 20-channel imaging microwave spectrometer on operational NOAA satellites beginning in 1990. The following types of investigations are under way:

Operational Weather Monitoring - temperature profiles, water vapor distribution, and rain bands
Atmospheric Research - stratospheric and mesospheric temperature profiles, water vapor profiles, trace constituent profiles, and winds
Polar Ice Studies - ice pack evolution and navigability
Land and Ocean - sea surface temperature, sea surface wind, oil spill observations, soil moisture, and snow cover

Several references describe these applications.[32,33,34,35,36]

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[31] P. M. Solomon, R. de Zafra, A. Parrish, and J. W. Barrett, "Diurnal Variation of Stratospheric Chlorine Monoxide: A Critical Test of Chlorine Chemistry in the Ozone Layer," Science, vol. 224, p. 1210, 1984.

[32] D. Staelin et al., "Microwave Spectroscopic Imagery of the Earth," Science, vol. 197, p. 991, 1977.

[33] D. Staelin, "Passive Microwave Techniques for Geophysical Sensing of the Earth from Satellites," IEEE Trans. Ant. & Prop., AP-29, p. 683, 1981.

[34] Applications, Review Panel Report, "High Resolution Passive Microwave Satellites," D. H. Staelin and P. W. Rosenkranz, eds., Final Report, Contract NAS5-23677, Research Laboratory of Electronics, M.I.T., April 1978. Available from NTIS as NASA Accession No. N81-71117.

D. Earth Satellite Positions and Tracking

To determine the precise positions of artificial earth satellites, one needs not only a means of measuring the position but also a fixed reference frame to which one can refer those positions. The astrometric grid of cosmic radio sources, established over the whole sky by radio astronomers, provides the only truly "fixed" reference system, to which other moving objects may be referred.

The location of those artificial satellites which transmit a radio signal can be established to exceptionally high precision by the radio astronomical technique of Very Long Baseline Interferometry (VLBI). The technique has been verified on the Global Positioning System (GPS) satellites, which are the primary position reference beacons for the next-generation of military, commercial, navigational and geodetic applications.

E. Spacecraft Navigation

Earth-based radio interferometry, precisely as practiced by radio astronomers, has provided a straightforward means of "triangulation" for spacecraft navigation.

- To monitor the position of the Apollo astronauts on the moon during their explorations aboard the Lunar Rover.
- To precisely locate sounding balloons released into the Venusian atmosphere by the Soviet Vega spacecraft mission.
- To establish the relative position of the Vega pathfinder flyby of Comet Halley with respect to the radio astronomical reference system of cosmic radio sources. (Necessary for course corrections during the Giotto spacecraft's close nuclear approach.)

F. Geodetic Studies and Crustal Dynamics

Radio astronomical VLBI observations have become a valuable tool for geophysicists in their study of the motion of the poles of the earth, changes in the rotation of the earth, and the nature of lunar-induced tides in the solid earth.

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[35] P. Gloersen et al., "A Summary of Results from the First NIMBUS 7 SMMR Observations," J. Geophys. Res., vol. 89, p. 5335, 1984.

[36] Manual of Remote Sensing, vol. 1, R. N. Coldwell, ed. (2nd ed.), American Society of Programmetry, 1984.

Geophysical studies of the earth's crustal dynamics depend on high precision measurements spread over several years. The positional accuracy obtained with radio astronomical VLBI observations is used to monitor the separation between geodetic radio telescopes to a few centimeters. Regional terrestrial deformations and global plate motions are thus measurable where the two telescopes span known fault lines and tectonic plates. The technique allows geophysicists to study pre- and post-earthquake seismic activity with the aim of earthquake prediction and a basic understanding of worldwide tectonic motions.[37]

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[37] A.E.E. Rogers et al., "Very Long Baseline Interferometry: The Mark III System for Geodesy, Astrometry, and Aperture Synthesis," Science, vol. 219, p. 51, 1983.

Attachment B

A BRIEF PROFILE OF THE
NATIONAL RADIO ASTRONOMY OBSERVATORY

March 1989

A BRIEF PROFILE OF THE NATIONAL RADIO ASTRONOMY OBSERVATORY

Since its founding in 1957, the National Radio Astronomy Observatory (NRAO) has been a major force in the development of radio astronomy. This field, pioneered in the United States, has blossomed to become a central element of modern astronomy throughout the world.

At the present time, the NRAO manages the operation of three major observing sites from its headquarters in Charlottesville, Virginia. The largest of these is the Very Large Array (VLA), a mobile array of twenty-seven 25-meter antennas. It is located on the Plains of San Agustin, near Socorro, New Mexico. NRAO is constructing a new telescope, the Very Long Baseline Array (VLBA). The VLBA, like the VLA, is a synthesis telescope simulating an extremely large single antenna by a distribution of smaller antennas operating in concert. In the case of the VLBA, the ten individual antennas will be spaced from Hawaii to the Virgin Islands and controlled from an operations center in Socorro, New Mexico.

The single-antenna radio telescopes of NRAO include the 140-foot diameter fully steerable telescope located at the original Green Bank, West Virginia site, and the 12-meter millimeter-wave telescope located on Kitt Peak near Tucson, Arizona. (Operation of the three-element Interferometer, also located in Green Bank, West Virginia, was discontinued for astronomical observing in 1978 when the VLA became operational; it is now operated by the NRAO exclusively for the U.S. Naval Observatory for purposes of time-keeping. Operation of the 300-foot diameter meridian transit telescope ceased with its catastrophic collapse on November 15, 1988.)

The NRAO is operated by Associated Universities, Inc. (AUI), an independent, not-for-profit research management corporation, under the terms of a Cooperative Agreement between the National Science Foundation (NSF) and AUI. The following responsibilities for AUI are included in the Scope of Work of this Cooperative Agreement:

- Staff, manage, operate, and maintain the facilities ....;

- Provide scientific, managerial, and logistic support in the conduct of research programs in radio astronomy and related fields. The research shall be carried out by visiting scientific investigators and the staff of the Observatory. The scientific merit of research proposed by visiting scientific investigators and by the Observatory staff shall be given the same consideration. The major criteria for the utilization of Observatory facilities shall be the scientific merit of the proposal, the competence of the individual or individuals, and the suitability of the Observatory facilities.

- Maintain a broad base research program at the Observatory in order to promote advances in and the utilization of knowledge in astronomy.

Provide facility and logistic support to university and NRAO research programs in radio astronomy and related fields.

- Engage in education programs in radio astronomy and related fields as may be appropriate to the operation of the Observatory and as is consistent with the Program Plan.

These requirements have characterized the role of the NRAO since it was founded.

The concept of a national observatory was unique when it was proposed in 1954--NRAO was the first national astronomical observatory. There were some who doubted that an open, visitor-oriented, national facility could efficiently serve its user community and at the same time provide a research environment that would be conducive to competitive research. The fact that NRAO has established and maintained the world standard in radio instrumentation and user service, together with the remarkable flood of scientific results from its users, is ample justification for the wisdom of providing such facilities.

USERS

The principal responsibility of the Observatory is to provide the astronomy community access to forefront research capabilities through the development of major national facilities.

Figure 1 shows the annual growth in the user group over the history of the Observatory, from the modest beginnings, before the first major telescopes were built, to over 650 long and short-term visitors today. The largest increase in the number of visitor-users occurred as the VLA entered full operation in 1981. The Observatory staff, both permanent scientists and postdoctorals (Research Associates), can be seen to represent about 7 percent of all NRAO users.

The number of institutions using NRAO telescopes has also grown dramatically over the years, with a 50 percent increase attributable to the VLA. Universities represent 64 percent of the institutions, other observatories and government laboratories 33 percent, and private industries the remaining 3 percent.

The overwhelming majority of these institutions lack the resources to design, build, maintain, and operate telescopes comparable to those at NRAO. Nevertheless, many of these institutions actually participate with NRAO in the design and fabrication of sub-elements of advanced systems. This includes not only individual university groups who bring their own observing equipment to NRAO telescopes but also working teams operating out of universities and government laboratories who assist in the design and, in some cases, actual construction of new instrumentation. Maintenance of such capabilities in these institutions is important to the future of NRAO as a national observatory.

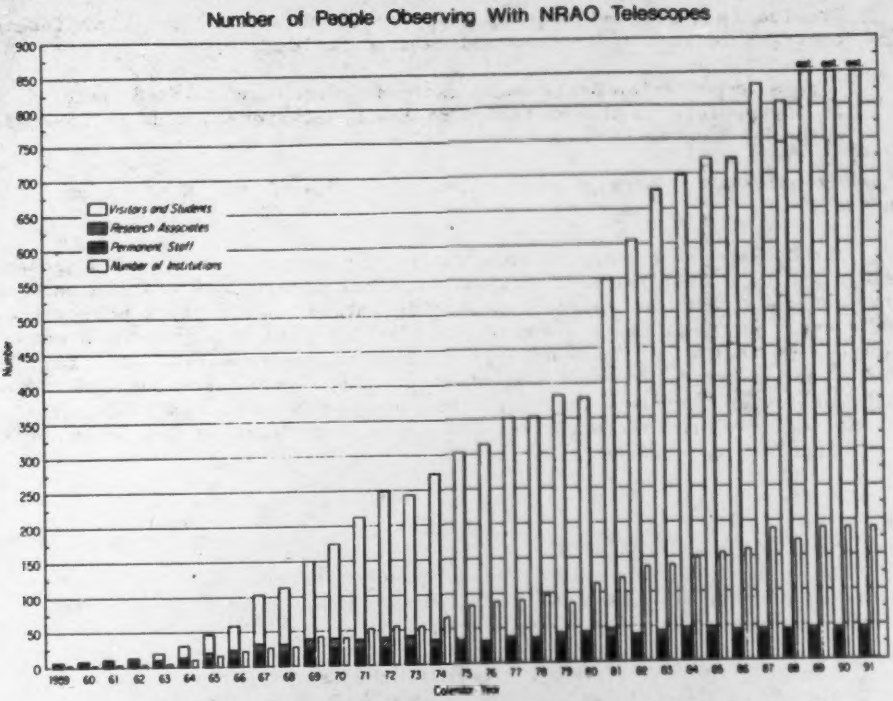


Fig. 1 **This bar chart shows for each calendar year the number of NRAO permanent research staff and the number of NRAO research associates (postdoctorals) who use the telescopes. In addition, it shows the total number of visitor-users of NRAO telescopes and the number of institutions from which the NRAO visitors come. The significant jump in these last categories for 1981 reflect the increased use of the VLA.**

It is also important to note that in keeping with a growing interdependence of all areas of astronomy, the NRAO user community is rapidly growing to accommodate new observers from optical, infrared, X-ray, and related areas.

The NRAO Student Program is illustrated in Figure 2. The vast majority of the student users are graduate students from universities having Ph.D. programs in astronomy. A large increase in graduate student users occurred when the VLA began operations. As with the other categories of users, this increase is due not only to the research opportunities the VLA presents but also to the operational convenience of this instrument which has been facilitated by the efforts of the Observatory staff.

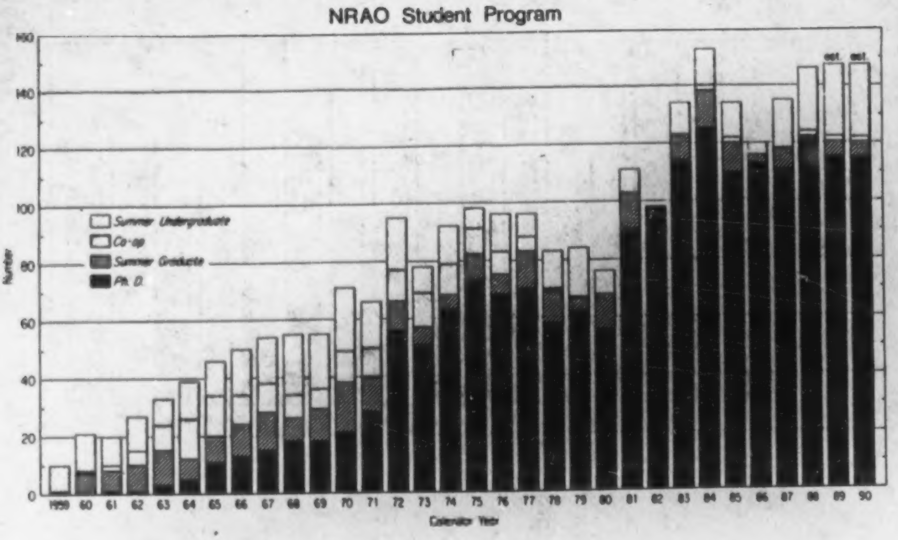


Fig. 2 This figure shows for each calendar year the number of Ph.D. students (including those few salaried at NRAO), NRAO co-op students, and NRAO summer students (undergraduate and graduate) who observed or worked at the NRAO during that year.

The Summer Student and Co-op Programs are a much smaller component of student usage of NRAO facilities, but these are important in the national programs. Both serve to introduce senior undergraduate and beginning graduate students to radio astronomy. The Summer Student Program focuses on astronomical research; the Co-op Program is conducted with university groups of engineers, applied physicists, and computer scientists. Both are important mechanisms for acquainting skilled scientists with issues of importance to the field of radio astronomy.

The extent to which NRAO is dedicated to its user community can be seen by examining Figures 3 and 4. Approximately 35,000 observing hours exist in principle in one year for all four of NRAO's telescopes taken together (4x24x365). The actual hours scheduled for observing with these telescopes are shown in Figure 3, where the recent totals are approximately 31,000, or 88 percent. The remaining 12 percent is scheduled for tests, calibration, preventative maintenance, installation of new equipment, and repairs.

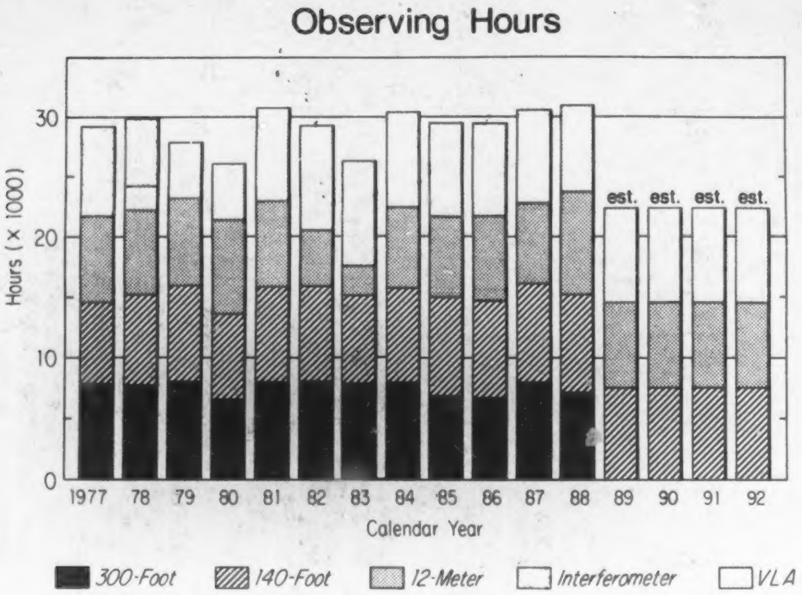


Fig. 3 This figure shows the hours scheduled for observing on each telescope during the last decade.

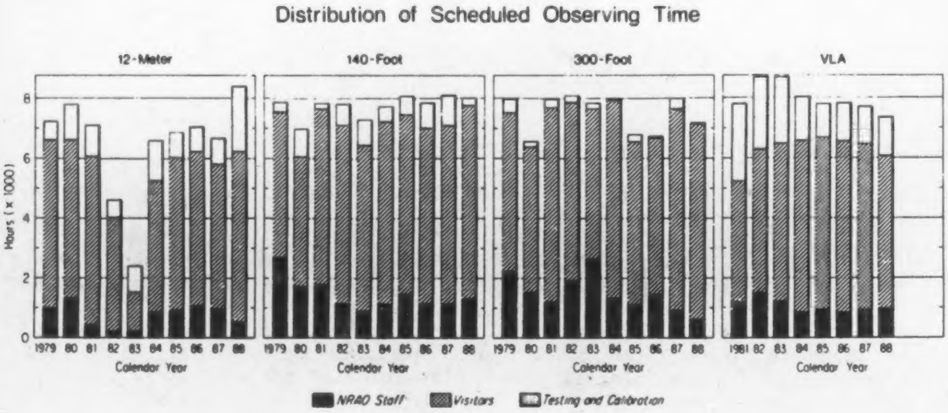


Fig. 4 These graphs show the number of hours scheduled for calibration and for observing by the NRAO staff and by visitors on each telescope system during the last decade.

The only periods when less than about 85 percent of the available time was scheduled for observing was in 1979-80 after the three-element Interferometer was closed and before the VLA began full operation, and in 1982-83 when the 36-foot millimeter-wave telescope was re-surfaced and re-christened as the 12-meter telescope. The telescopes, which operate 24 hours a day, are efficiently scheduled to produce as much observing as possible.

How is the observing time allocated to staff and visitor users? Different projects require differing amounts of time, but all grants of observing time are made on the basis of scientific merit. All proposals, from staff and visitors alike, are refereed and graded for merit by anonymous referees selected from the community. The detailed scheduling is done by the site directors, with the assistance of a special committee in the case of the VLA. The rule that Observatory staff compete for time on the same footing as visitors is fundamental and has contributed a great deal to the excellent relationship between the Observatory and its user community.

Figure 4 shows the actual observing time distribution among NRAO scientific staff, visitors, and calibration and test time. Over time, the NRAO staff has qualified to utilize about 15 percent of the observing time, with some variation from telescope to telescope. This level of use is judged to be adequate to enable the Observatory staff to maintain a competitive research program of its own, which is necessary if the Observatory is to continue to provide effective leadership within the U.S. radio astronomy community.

STAFF AND OPERATIONS

The growth of NRAO's permanent full-time staff over the history of the Observatory is shown in Figure 5. The steady, smooth growth up to 1970

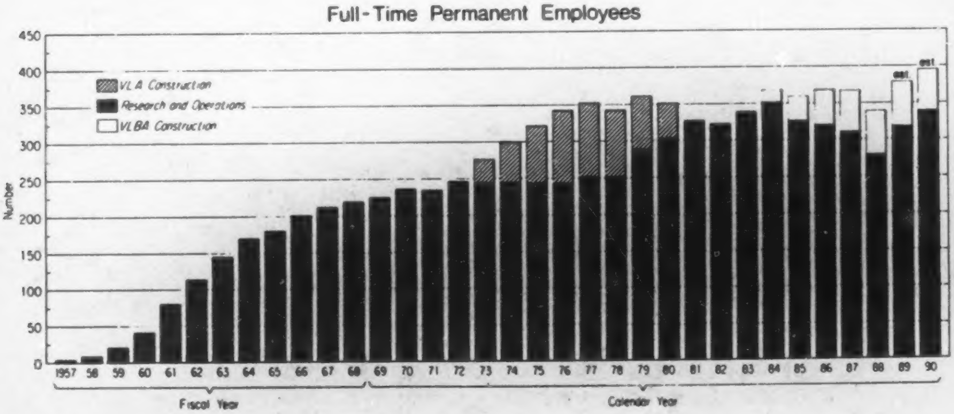


Fig. 5 This figure shows the total number of NRAO full-time, permanent employees at the end of each year, projected into the future.

accompanied the construction of the 300-foot, 140-foot, millimeter-wave, and three-element Interferometer. The size of the operations staff was constant throughout most of the VLA construction period and increased in response to major new user requirements as operation of that instrument began in 1979. The recent decline in staff reflects the unbroken 5-year decline in budget levels. Personnel levels throughout the VLBA construction period are expected to follow the VLA pattern. Additional operations staff will certainly be required if this major new facility is to be operated efficiently at its completion. Many, but not all, of these new operations staff are expected to be drawn from the construction staff.

It should be noted that following full operation of the VLA the number of NRAO users doubled (100%) and is still increasing as is the number of student users, but the staff to serve these users is now only equal to that of 1979, the year that marked the half-way point in assembling the VLA staff.

The composition of the scientific staff at NRAO is given in Table 1, where the scientific staff is defined as all professional employees holding a Ph.D degree. The total Ph.D. staff is 69 employees, 20 percent of all full-time permanent employees. Of these 69, 24 form the basic research staff, or 7 percent of all full-time permanent employees. Twenty-four of the 69 members of the Ph.D. staff hold tenured positions, or 7 percent of the staff. These numbers are consistent with the original intention that the Observatory have a small, dedicated research and development staff.

Table 1

Ph.D. Staff Classification/Distribution

Basic Research Staff	Total	
Postdoctorals	5	
Associate Scientists	1	
Scientists	15	
Senior Scientists	4	
Total (17 tenured)		25
Other Ph.D. Staff		
Operations/Management	16	
Electronics	8	
Computing	11	
VLBA Construction	9	
Total (7 tenured)		44
Total Ph.D. Staff (24 tenured)		69
NRAO Staff		
Operations	287	
Construction: VLBA	55	
Construction: Voyager	9	
Total Staff		351

Fraction of staff with Ph.D. degree - 69/351 - 20%
Fraction of Ph.D. staff with tenure - 24/69 - 35%
Fraction of total staff with tenure - 24/351 - 7%

LONG RANGE PLANS

NRAO has been engaged for some time in planning for two new major facilities: the Millimeter Array and a large-aperture, fully-steerable radio telescope that would replace both the 300-foot and 140-foot telescopes. Until recently the Millimeter Array received more time and attention; the loss of the 300-foot telescope has switched the priority.

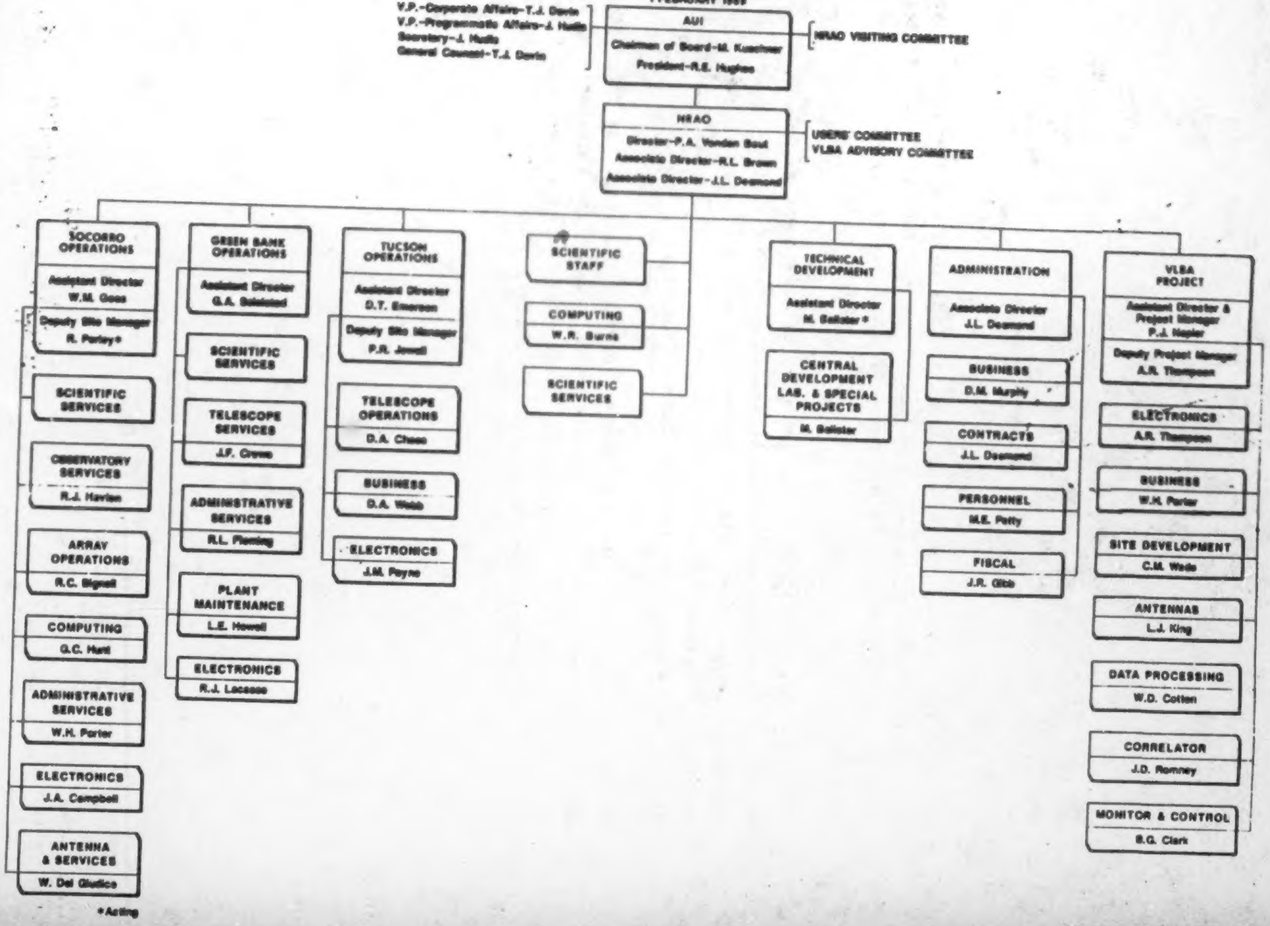
Following the collapse of the 300-foot telescope on November 15, 1988, the Observatory staff and user community worked to define the scientific requirements and technical specifications of a replacement telescope. It is clear that there is a compelling scientific case for a fully steerable, high performance, large aperture radio telescope and that new technology makes it possible to build such a telescope, superior to any existing fully steerable antenna, at reasonable cost. The estimated budget for the entire project is 75 M$ (1989). The telescope could begin operations in late 1994/early 1995.

The scientific program for the telescope and the implied technical requirements were discussed in a workshop held in Green Bank, December 2-3, 1988, and subsequently refined by the Observatory staff. The telescope will make major contributions to the study of the structure of the universe, the gaseous content of galaxies, solar/stellar phenomena, molecular clouds and star formation, evolution of galaxies, the solar system, the nature of radio galaxies and quasars, fundamental catalogs, as well as applications to space VLBI. Inspired by the diversity of scientific needs, a telescope design has been specified which offers major advances over existing instruments to every relevant area of research.

The Millimeter Array (MMA) is a synthesis telescope like the VLA, designed to provide detailed images of those regions of space in which stars form. Pioneered in the United States, astronomy at millimeter wavelengths has been extraordinarily fruitful in refining our understanding of the physical and chemical processes which lead to the formation of stars such as the sun, planets and, indeed, life itself. The scientific need now is for high resolution images that will permit a more precise view of these phenomena. The MMA is astronomy's response to this need.

The Millimeter Array will consist of approximately 40 antennas, each 7.5 meters in diameter; the antennas will be distributed over an area nearly 3 km in extent. Since cosmic radiation at millimeter wavelengths is absorbed in the earth's atmosphere, and this effect is detrimental to millimeter astronomy, the MMA will be located at a high altitude site probably in the southwestern portion of the U.S. The simultaneous need for precision MMA antennas that will permit sensitive observations at short millimeter wavelengths and the need for the antennas to survive and operate in the harsh environment characteristic of high altitude sites present a unique technological challenge for the NRAO. The Millimeter Array is estimated to cost 75-90 M$.

NATIONAL RADIO ASTRONOMY OBSERVATORY ORGANIZATION CHART
1 FEBRUARY 1989


V.P.-Corporate Affairs-T.J. Davis
V.P.-Programmatic Affairs-J. Hadlo
Secretary-J. Hadlo
General Counsel-T.J. Davis
AUI
Chairman of Board-M. Kuschner
President-R.E. Hughes
NRAO VISITING COMMITTEE
NRAO
Director-P.A. Vanden Bout
Associate Director-R.L. Brown
Associate Director-J.L. Desmond
USERS' COMMITTEE
VLBA ADVISORY COMMITTEE
SOCORRO OPERATIONS
Assistant Director W.M. Goss
Deputy Site Manager R. Perley*
SCIENTIFIC SERVICES
OBSERVATORY SERVICES
R.J. Havlen
ARRAY OPERATIONS
R.C. Bignell
COMPUTING
G.C. Hunt
ADMINISTRATIVE SERVICES
W.H. Porter
ELECTRONICS
J.A. Campbell
ANTENNA & SERVICES
W. Del Giudice
GREEN BANK OPERATIONS
Assistant Director G.A. Seielstad
SCIENTIFIC SERVICES
TELESCOPE SERVICES
J.F. Crowe
ADMINISTRATIVE SERVICES
R.L. Fleming
PLANT MAINTENANCE
L.E. Howell
ELECTRONICS
R.J. Lacasse
TUCSON OPERATIONS
Assistant Director D.T. Emerson
Deputy Site Manager P.R. Jewell
TELESCOPE OPERATIONS
D.A. Chase
BUSINESS
D.A. Webb
ELECTRONICS
J.M. Payne
SCIENTIFIC STAFF
COMPUTING
W.R. Burns
SCIENTIFIC SERVICES
TECHNICAL DEVELOPMENT
Assistant Director M. Balister*
CENTRAL DEVELOPMENT LAB. & SPECIAL PROJECTS
M. Balister
ADMINISTRATION
Associate Director J.L. Desmond
BUSINESS
D.M. Murphy
CONTRACTS
J.L. Desmond
PERSONNEL
M.E. Petty
FISCAL
J.R. Gibb
VLBA PROJECT
Assistant Director & Project Manager P.J. Napier
Deputy Project Manager A.R. Thompson
ELECTRONICS
A.R. Thompson
BUSINESS
W.H. Porter
SITE DEVELOPMENT
C.M. Wade
ANTENNAS
L.J. King
DATA PROCESSING
W.D. Cotton
CORRELATOR
J.D. Romney
MONITOR & CONTROL
B.G. Clark
*Acting

Biography

Paul Adrian Vanden Bout

Paul Vanden Bout was born on June 16, 1939 in Grand Rapids, Michigan. He attended Calvin College as an undergraduate and received his A.B. degree in 1961. He received his Ph.D. degree from the University of California, Berkeley, in 1966 in physics.

From 1967 to 1970 he was in the physics department of Columbia University as a postdoctoral and assistant professor. Starting in 1970 he joined the astronomy department of the University of Texas at Austin, serving as department chairman from 1978-82. In 1985 he was appointed director of the National Radio Astronomy Observatory.

He is a member of the American Astronomical Society, the International Astronomical Union, the U. S. National Committee of the International Radio Science Union, and the American Association for the Advancement of Science, and is a fellow of the American Physical Society.

3/89

Mr. **Walgren**. Thank you, Dr. Vanden Bout.

We will turn to Dr. Wolff.

STATEMENT OF DR. SIDNEY C. WOLFF, DIRECTOR, NATIONAL OPTICAL ASTRONOMY OBSERVATORIES

Dr. **Wolff**. Mr. Chairman, thank you very much for the opportunity to appear here today.

In my presentation, I would like to focus on the issues related to optical astronomy, and in my written testimony I presented a graph that summarizes the history of funding for astronomy within the NSF.

As everyone has pointed out, the funding for NSF as a whole has increased since 1984 to 1990 in inflation-corrected dollars by about 35 percent. Funding for the National Optical Astronomy Observatories has declined by about 10 percent over that period of time. And again, as people have pointed out, if you allow for construction projects, the funding for operation of the facilities has actually declined by about 20 percent.

In terms of purchasing power, the budget for the National Optical Astronomy Observatories now is what it was in the early 1960s when we operated only a few telescopes on a single site, Kitt Peak, rather than the three observatories that we operate now, including observatories in New Mexico and Chile.

This decrease in funding for optical astronomy within the NSF is sharply at variance with the increase in funding that is being provided by agencies both here and abroad. During the next 10 years, NASA, for example, plans to launch four space observatories which, in combination with ground-based facilities, will make it possible for the first time to observe at all wavelengths of the electromagnetic spectrum from gamma rays to radiowaves.

The European Space Agency and Japan are also planning major initiatives in space. Both of these groups explicitly recognize the requirement for a major enhancement in ground-based observing capabilities for optical astronomy in order to support their space missions.

The European Community, through the European Southern Observatory, has already firmly committed $240 million toward the construction of four 8-meter ground-based telescopes. The collecting area of these telescopes—that is, the area of glass mirror in these telescopes—will exceed the total collecting area of all the telescopes now in operation through the world.

Japan is planning to seek funding for a 7.5-meter telescope, which they will build in Hawaii.

The only funded large telescope in the United States at the present time is the 10-meter Keck telescope, which is also being built in Hawaii. This is a privately funded telescope and will have a 10-meter diameter and will be open for use only by astronomers at Caltech, the University of California, and the University of Hawaii.

In order to provide new optical facilities for the remainder of the U.S. astronomical community, the National Observatories do plan to propose the construction of two 8-meter telescopes, and again in the written testimony, there is a sketch of what those telescopes would look like. We plan to place one of those telescopes in Chile and the other on Mauna Kea. In order to help provide funding for these telescopes, we are currently seeking international partners.

Now, why should the funding for astronomy increase? There are three reasons: The scientific payoff will be very great; the application of new technologies will revolutionize the types of observations that can be made; and the investment must be made in a timely fashion to achieve the maximum benefit.

With respect to scientific payoff, you have only to read the newspapers to realize something about the remarkable discoveries that are being made almost daily in astronomy. I am sure most of you are familiar with the work on the supernova that exploded in 1987, and analysis of the data on that supernova has confirmed a great many of our theoretical ideas about what happens when stars die.

With new infrared techniques, we can peer into dark clouds where star formation is going on and see the process of star formation. We can also, we believe now, begin to study the process of the formation of planetary systems around other stars as well.

The universe even offers us a time machine so we can observe it the way it used to be. This photograph shows the most distant galaxy that we know of right now. This galaxy is so far away that it takes light 10 billion years to travel from this galaxy to us. That means we are seeing it as it was 10 billion years ago. And you have to remember that we think the universe itself is only 13 billion years old, so we are seeing things as they were when the universe was only about 20 percent as old as it is now.

One of the primary goals of the next generation of large telescopes is to study very young galaxies like the one I showed you so that we can tell what they are made of, what kinds of stars they have in them, how old those stars are, and therefore, something about how old the universe itself truly is.

Technology is also playing an increasingly important role in astronomy. Technology breakthroughs are what make it possible to build telescopes larger than any now in operation. For example, work at the University of Arizona has succeeded in casting large, light-weighted but relatively stiff mirrors, and these mirrors will be the key to constructing the next generation of telescopes. This work, as I said, is partly supported by the NSF.

In other areas as well, including especially infrared and optical detectors, fiberoptics, computers, image enhancement techniques, technology is revolutionizing astronomy, and astronomy in turn is driving the development of new technologies.

Timeliness is another compelling argument for increasing the investment is ground-based astronomy. Some observations simply cannot wait. We are heading toward what may prove to be the most intense maximum in solar activity on record. Large flares are becoming increasingly common. Flares and other forms of solar activity can disrupt communications on Earth, cause auroral displays, as they did this week, and speed the reentry of spacecraft into the Earth's atmosphere, and even pose a danger to astronauts in Earth orbit. The possibility exists that we can learn to predict flares, but only if we have the resources to study the sun in detail during the period of maximum activity, which is expected to occur in 1991.

One of the primary missions of NSF when it was founded in the late 1950s was the construction of National Observatories, specifically the National Radio Astronomy Observatory in Kitt Peak. I have been told, although I have not verified it, that in the late 1950s one-quarter of the NSF budget was devoted to astronomy.

The U.S. National Observatories that were built then have been enormously successful in that they have made possible the development of strong astronomy programs at universities throughout the country. Astronomers from 39 States and the District of Columbia used the optical facilities last year. The U.S. approach of providing National Observatories has been followed as a model throughout the world.

The NSF funding priorities now place the U.S. National Observatories at risk. The collapse of the 300-foot telescope stands as a symbol of what has happened to NSF-funded programs in astronomy. U.S. astronomers must rely on aging facilities that, while still productive, simply cannot match the capabilities of the modern facilities now under construction in other countries.

Attention has been focused on the issue of whether or not the Green Bank telescope should be replaced. The scientific case for doing so is strong, but the scientific case is at least equally strong for a number of other projects, including the national 8-meter telescopes which have previously been endorsed by various planning efforts by the astronomy community.

What is required is not merely replacement of the Green Bank facility but a revitalization of the whole field of ground-based astronomy. This revitalization could be achieved if astronomy were to share from now on in the growth of funding—that is, a doubling of the budget over a 5-year period—which has been planned for the NSF.

Thank you.

[The prepared statement of Dr. Wolff follows:]

TESTIMONY TO THE HOUSE OF REPRESENTATIVES

SUB-COMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY

March 14, 1989

Sidney C. Wolff
Director
National Optical Astronomy Observatories

Mr. Chairman, Honorable Members of Congress:

I wish to thank you for this opportunity to present my views on the proposed NSF research program in astronomy for fiscal year 1990. The adequacy of the support requested for astronomy by the NSF must be evaluated in terms of the overall research goals and opportunities identified by astronomy programs both in the United States and abroad, and in terms of plans for facility construction in space and on the ground. In my presentation I will focus on issues related to optical astronomy, but first I will describe how groundbased astronomy fits into the future directions of astrophysical research.

Remarkable new techniques are soon to become available that will revolutionize our knowledge of the universe in which we live. In order to exploit the full scientific capabilities of these new techniques, which include the ability to observe ultra-high energy radiation from space, it is necessary to build powerful new optical groundbased telescopes, and I will describe the plans both here and abroad for doing so.

Groundbased astronomy in the national observatories, which are the only observatories that are open to the entire U.S. community on a competitive basis, receives its support almost entirely from the NSF. The history of that funding will be reviewed; far from sharing in recent increases in funding for NSF, the operations budgets of the national centers have declined in real terms. Specific proposals will be offered for revitalizing groundbased astronomy.

The New Astronomies

We stand on the threshold of a new era in astronomical research. Over the next decade it will for the first time become possible to observe in all the wavelength regions of the electromagnetic spectrum. NASA will launch long-lived space observatories designed to make observations of gamma rays (Gamma-Ray Observatory) and ultraviolet radiation (Hubble Space Telescope), has begun work on the Advanced X-Ray Facility, and will request funds for infrared airborne and orbiting observatories. European countries, which work together through the European Space Agency, and Japan have ambitious plans of their own for astrophysical observatories in space.

There will be additional astronomical initiatives in areas that have previously been regarded as the domain of physics. Indeed, because the physical conditions reached in certain astronomical sources, such as neutron stars, and at certain times in the evolution of the universe, including the high-temperature, high-density phase that characterized the first second after the big bang, cannot be duplicated in earth-bound laboratories, astronomical observations offer the only way of testing certain fundamental theories of the elementary particles that make up our material world.

Specific projects now being explored include more work on the measurement of solar neutrinos; a search for gravitational wave radiation, weak perturbations which the theory of general relativity predicts should be produced by such events as supernova explosions; and the search for ultra-high-energy gamma rays and cosmic rays.

Perhaps the most challenging problem in astrophysics and physics alike is the identification of the so-called "dark matter." Observations of the motions of stars within galaxies and of galaxies within clusters of galaxies suggest that the force of gravity is at least ten times, and perhaps as much as 100 times, stronger than one would predict by simply calculating the gravitational force produced by all of the matter that we can actually *see*--stars, dust, and gas. It is believed that 90 percent of the observed gravitational effect is due to invisible matter. There are theories of the formation and evolution of matter in the universe that suggest that this invisible matter is diffuse, that it is to be found throughout space, and that it is formed of a hitherto unknown type of elementary particle. If this hypothesis is true, then it may be possible to detect dark matter particles in physics laboratories, and a variety of experimental techniques are being devised to attack this problem.

Optical Astronomy in the Era of the New Astronomies

Far from reducing the need for groundbased optical telescopes, observations in new wavelength regions very often *require* optical data for their successful interpretation. Because of the temperatures that are typical of most astrophysical objects and because of basic properties of the structure of atoms, the optical region of the spectrum is rich in diagnostic information about the composition, motions, dynamics, temperatures, and densities of astronomical sources.

Even identifications of sources of x-rays, gamma rays, or infrared radiation usually depend on optical imaging and spectroscopy. For example, it is very often impossible to distinguish stars from galaxies and quasars on the basis of x-ray observations alone. Already more than one-quarter of the observing time of the telescopes of the national observatories is devoted to follow-up of space observations, and this demand can only increase with the launch of the Hubble Space Telescope (HST) and other orbiting observatories.

Astronomical sources that are strong emitters of x rays, gamma rays, or infrared radiation are often faint in the optical region and can be detected only with the largest telescopes. The difficulties of optical studies are compounded by the fact that what is most useful is spectroscopy of faint sources, which is required to determine their compositions and motions. Spacecraft experiments to date have emphasized imaging in a broad range of energy. For optical observations from the ground, what is usually done is to disperse the light into a spectrum, a procedure equivalent to observing only in a very narrow energy range. Greater sensitivity is required for spectroscopy than for broad-band imaging.

Fortunately, technical advances have made it possible for optical astronomy to respond to these new demands. Rapidly improving detectors are becoming so sensitive that they are able to measure nearly every photon that reaches them. The areas of these detectors are increasing as well, so that it has become possible to observe either larger areas of the sky or broader spectral regions with a single exposure.
For infrared astronomy, the improvements in sensitivity and areal coverage have increased the efficiency of existing telescopes by factors of as much as 10,000 in the last three years. The National Optical Astronomy Observatories (NOAO) have worked closely with commercial manufacturers to test, characterize, and modify products developed for other purposes, including defense applications, for use in astronomy.

Astronomers are, however, rapidly approaching the limits of what can be achieved by improving detectors. There are practical limitations to the size of detectors, and once all the photons are detected no further gains in sensitivity are possible. The only way to observe still fainter sources is to build larger telescopes.

Large Optical Telescopes--Feasibility and Justification

Just as technology has led to remarkable improvements in detectors, so too it now makes possible the construction of telescopes that are both larger in terms of aperture and better in terms of image quality than any now in use. Furthermore, the use of new technologies, which permit the manufacture and mounting of much thinner, and therefore lighter weight, mirrors than were used in older telescopes, makes it possible to lower significantly the cost of construction.

For only twice the cost, corrected for inflation, of the existing 4-m telescopes, we can now build telescopes that will be 16 times more sensitive for certain types of limiting observations. A gain of a factor of 4 is achieved through increased collecting area; these telescopes will be 8 meters in diameter. Another factor of 4 is due to the improved image quality that can be achieved with modern mirror-polishing and testing techniques.

One research program that can only be tackled by these large telescopes is the observational study of the formation and evolution of galaxies. With existing telescopes, astronomers can detect galaxies that are so far away that light takes about 10 billion years to reach us. We are observing those galaxies as they were when the universe was only about 20 percent as old as it is now. The measurements show that much of the important evolution of galaxies takes place during the time that the universe was between 20 percent and 50 percent of its present age.

To understand how galaxies form and evolve, however, we must know more. We must detect galaxies even earlier in the history of the universe by imaging still more distant, and therefore, fainter galaxies. We must also dissect the light (a technique known as spectroscopy) of the very distant galaxies already discovered so that we can determine their compositions, masses, stellar populations, dust and gas content, and internal dynamics. There is also evidence that collisions with other galaxies play a dominant role in shaping galaxy morphology, and spectroscopy holds the key to understanding the effects of galaxy interactions.

Space telescopes will play a key role in imaging and identifying young galaxies. Large groundbased telescopes, however, will be required for detailed analysis of the optical light of these very distant and very faint galaxies. An 8-m telescope has nearly nine times the collecting area of the Hubble Space Telescope and therefore nine times the sensitivity for faint object spectroscopy. Further gains can be achieved because groundbased telescopes can more readily be equipped with state-of-the-art instrumentation since the lead time for building and commissioning groundbased instrumentation is much shorter. Furthermore, costs on the ground are very much lower than in space. A fully instrumented 8-m telescope will cost no more than 5 percent of what the Hubble Space Telescope cost; equivalently, the cost of an 8-m telescope on the ground is about the same as the cost of a single instrument for HST. What can be done from the ground should be done from the ground.

Large Optical Telescopes--Plans

Providing for access to the next generation of 8-m class telescopes is seen as the central issue for groundbased astronomy throughout the world during the next decade. Most of the countries with substantial astronomy communities have already made provision for the construction of nationally accessible 8-m class telescopes or are actively attempting to initiate such projects.

Two projects in this category are already funded. The European Southern Observatory has received a commitment from its member nations to provide $240 million over the next ten years to build four 8-m telescopes in Chile. In the United States, Caltech and the University of California have committed nearly $100 million toward the construction and instrumentation of a private 10-m telescope on Mauna Kea on the Island of Hawaii. The bulk of the construction funds have been provided by the Keck Foundation.

This early and firm commitment by ESO to the construction of four 8-m telescopes continues a trend to greatly increased emphasis in Europe on groundbased astronomy, a trend which has not been matched in the United States. Table 1 lists the telescopes now in operation with apertures of 3.0-m and greater available to European and United States astronomers. The total collecting area is comparable, but only two of the U.S. telescopes were completed in the past fifteen years. Six of the seven European telescopes were completed in the past decade.

TABLE 1

EXISTING TELESCOPES WITH APERTURES ≥ 3 METERS

OWNER	NAME/LOCATION	APERTURE (Meters)	AREA (Square Meters)
U of Cal.	Shane/Lick Obs.	3.0	7.1
NASA	IRTF/Mauna Kea	3.0	7.1
NOAO	CTIO	4.0	12.6
NOAO	Mayall/Kitt Peak	4.0	12.6
Smithsonian	MMT/Mt. Hopkins	4.5	15.9
Caltech	Hale/Palomar	5.1	20.4
	Total Area (US)		75.7
ESO	NTT/La Silla	3.5	9.6
FRG	German-Spanish/ Calar Alto	3.5	9.6
Canada/France/ Hawaii	CFHT/Mauna Kea	3.6	10.2
ESO	3.6-m/La Silla	3.6	10.2
UK	UKIRT/Mauna Kea	3.8	11.3
UK/Australia	AAT/Siding Spring	3.9	11.9
UK	Herschel/La Palma	4.2	13.9
	Total Area (European)		76.7
Russia	SAO/Zelenchuk	6.0	28.0

Other 8-m class projects are seeking funding. Japanese astronomers are planning to request funding for a 7.5-m national telescope on Mauna Kea. The United Kingdom and Canada each have developed long range plans that call for funding one-half of the cost of an 8-m telescope, with the intention of finding partners to complete the projects. The Universities of Arizona and Ohio State have signed a memorandum of understanding with Italy that calls for construction of a private telescope with two 8-m mirrors on a single mount; this telescope will be placed on Mount Graham in southern Arizona. The Carnegie Institution of Washington, in conjunction with Arizona and possibly Johns Hopkins University, has indicated an intention to seek funding for an 8-m private telescope in Chile.

NOAO serves the majority of the U.S. astronomical research community, which is not represented by the private projects mentioned above and will not have open access to the completed facilities. NOAO therefore plans to propose the construction of two national 8-m telescopes. One would be placed on Mauna Kea; the other would go to Chile where NOAO currently operates the Cerro Tololo Inter-American Observatory. This initiative, if fully funded and if all of the private fund raising efforts in the U.S. are successful, would restore the existing parity with Europe in terms of groundbased observing facilities.

NOAO's plan for two 8-m telescopes represents a considerable scaling back of the plan put forth nearly a decade ago by the most recent National Academy of Sciences Astronomy Decade Study, chaired by Dr. George Field (Astronomy and Astrophysics for the 1980s, Volume I, National Academy Press, 1982). This study called for the construction of a 16-m equivalent aperture telescope, the so-called National New Technology Telescope. The scaling back has come about for two reasons. First, we now know that the atmosphere over groundbased sites of the caliber of Mauna Kea can produce much better image quality than was realized at the time of the decade survey; to realize the full advantage of these sites it is necessary to produce telescopes of much better optical quality than those now in use, and it seems prudent to resolve these very difficult technical issues at the 8-m size first. Second, given the history of NSF funding for astronomy over the past decade and the need to resolve the problem of the federal budget deficit, it seems unrealistic to expect to receive funding in the near future for a 16-m national telescope.

We have been encouraged by the NSF to seek partners for the 8-m projects so that NSF funds would need to be provided for no more than one telescope. We hope to establish a joint program with the United Kingdom or Canada or both. Success in this effort is by no means assured, but the scientific goals and technical requirements established independently by all three countries are mutually consistent. We believe that such international cooperation can be mutually beneficial, can serve broader national policy objectives, and can help us get started with at least part of the national 8-m telescope program.

A drawing of the NOAO 8-m telescope design is included as Figure 1. The structure is obviously different from existing telescopes, and these structural changes are only one of many design innovations.

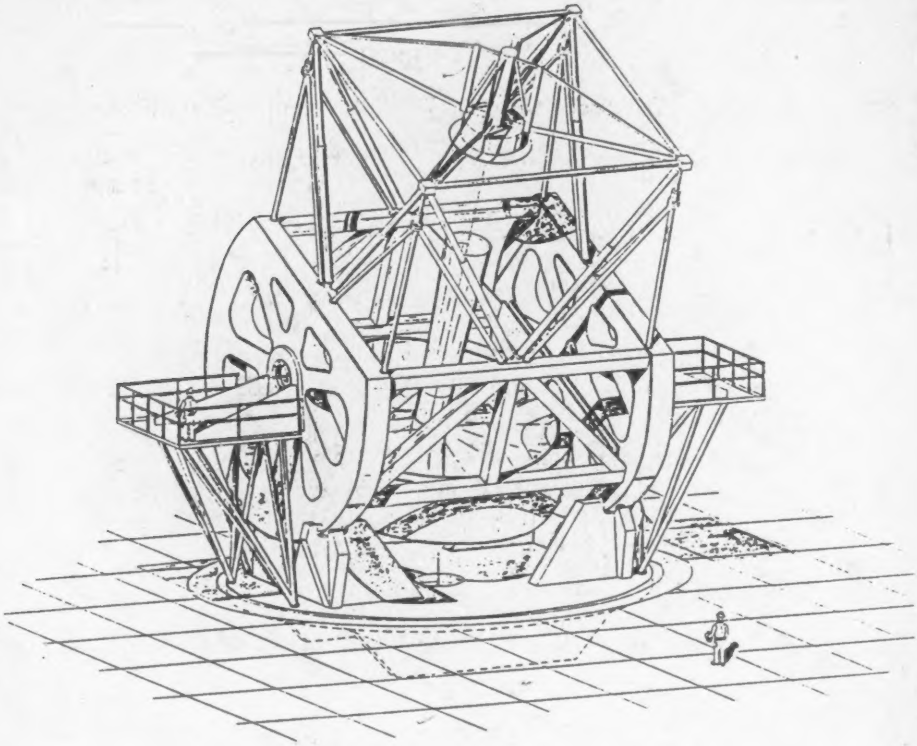


Figure 1. A drawing of the 8-m telescope, for which NOAO is seeking funding.

Table 2 lists the large telescopes that are in advanced stages of planning both in this country and abroad. If all were built, then the combination of privately funded and nationally accessible facilities in this country would maintain a competitive position for the U.S. The national facilities for the U.S. will be placed on sites both in Chile and in Hawaii where large telescopes have been, or soon will be, built by other groups. When techniques for optical and infrared interferometry are developed, the NOAO telescopes, like the ESO 8-m telescopes, could become components of telescope arrays with unprecedented power.

TABLE 2

FUNDED TELESCOPES WITH APERTURES > 6.0 METERS

OWNER	NAME/LOCATION	APERTURE (Meters)	AREA (Square Meters)
UC/Caltech	Keck/Mauna Kea	10.0	78
Smithsonian	MMT Upgrade/ Mt. Hopkins	6.5	33
ESO	VLT/Chile	4x8	200

PROPOSED TELESCOPES WITH APERTURES > 6.0 METERS

OWNER	NAME/LOCATION	APERTURE (Meters)	AREA (Square Meters)
NOAO/UK?	NOAO/Mauna Kea	8.0	50
NOAO/Canada?	NOAO/Chile	8.0	50
AZ/OH/Italy	Columbus/Mt Graham	2x8	100
Carnegie	Magellan/Las Campanas	8.0	50
AZ/Hopkins/ Japan	JNLT/Mauna Kea	7.5	44

TOTAL AREA OF ALL PLANNED AND FUNDED LARGE TELESCOPES

US	286
Other Countries	319

To serve the sharply increasing demand for observations that do not require the largest groundbased telescopes, NOAO also plans to participate with universities in the construction and operation of at least two additional 3.5-m telescopes. Most of the construction funds will be provided by the universities at no cost to the Federal Treasury. NOAO will then operate the telescopes for a fixed period of time, probably 15 to 20 years, and observing time will be shared between the universities and the national community in proportion to the financial commitments. The telescopes will be designed to meet specific scientific requirements, such as the support of space missions, and will be designed from the outset to have low maintenance costs. The incremental costs of operating such telescopes on existing sites is small. If NOAO's budget does not improve during the four years required for construction, then the operating funds would be obtained by closing existing small telescopes.

Another example of powerful collaborations in the development of plans for new, large optical telescopes is the Large Earthbased Solar Telescope, or LEST. A consortium of ten nations is designing the world's largest solar telescope to probe the finest details of the atmosphere of the nearest star -- our Sun. The Sun provides us with an unparalleled plasma physics laboratory, to probe processes of tremendous importance for astrophysics, as well as the entire solar-terrestrial environment, and the solar physicists of the world are joining focus to cooperatively explore this important area of research.

In short, NOAO is aggressively seeking partial funding for the projects that it is proposing through the formation of consortia with other countries and with U.S. universities. Only that portion of each project that is funded by the NSF will result in facilities that are open to the entire U.S. community.

Adequacy of NSF Support for Astronomy

The adequacy of NSF support for astronomy must be measured against the opportunities presented by the field itself, by available technology, by our understanding of elementary particle physics, and by the very real challenge to U.S. leadership that is being mounted abroad. With respect to this standard, funding over the past decade has been wholly inadequate. In his testimony before this committee last year, Dr. Arthur Walker, who is here again today, said, "The situation, especially in astronomy, has now reached the point that the basic infrastructure of the national observatories, and of university based research groups has begun to crumble, and may, if the situation is not addressed immediately, suffer damage that will require years to repair. If this occurs, the competitive situation in which we find ourselves, with loss of leadership having already occurred in a few fields, about to occur in others, and with our leadership being strongly challenged almost everywhere, may deteriorate very rapidly. I urge you to address the question of the low priority accorded the physical sciences in the NSF budget, over the past four years especially, immediately in the FY 1989 authorization."

A floor was subsequently placed under the astronomy budget by the Congress, and that action was certainly helpful. The budget request for FY 1990, however, perpetuates the funding problems faced by astronomy.

Figure 2 shows the funding received by NOAO and by the Astronomy Division within NSF, since 1984 and corrected for inflation to FY 1988, compared to the funding for NSF as a whole. The figure includes the funds requested for FY 1990 in the President's budget submission to Congress. If this request is accepted, then in terms of purchasing power, the budget for NOAO from FY 1984 through FY 1990 will have declined by 10 percent while the budget overall of the NSF has increased by 35 percent.

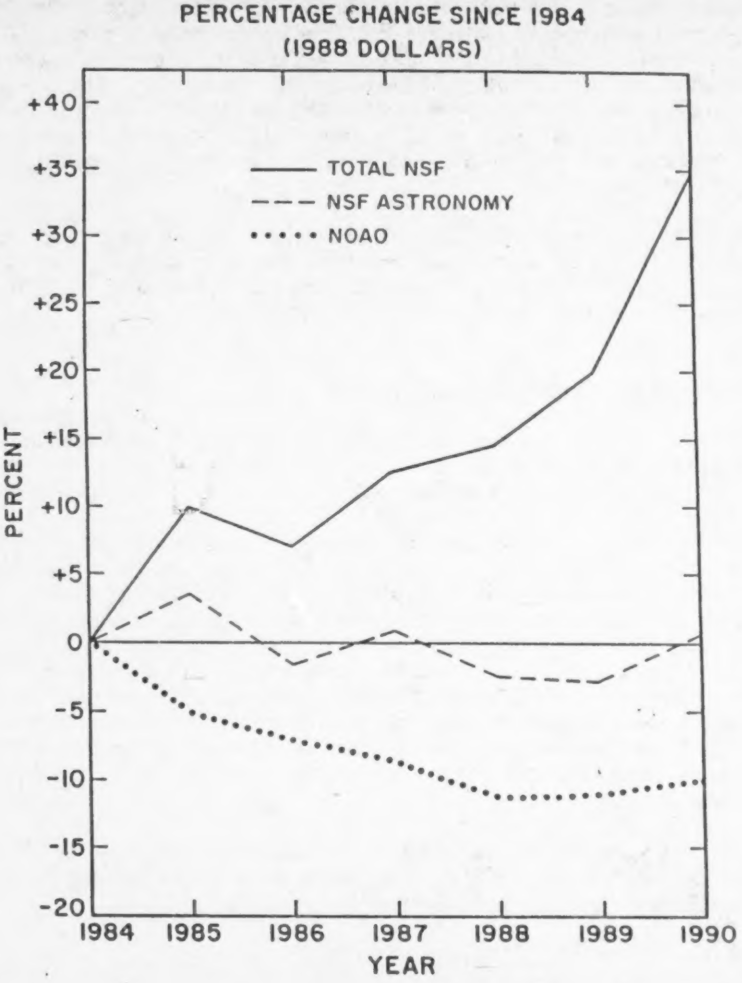


Figure 2. The budgets for NSF, the astronomy division within NSF, and NOAO from 1984 to 1990. All figures have been corrected to FY 1988 dollars. For FY 1990 an inflation rate of 6 percent was assumed.

The FY 1990 request, therefore, does nothing to reverse the funding trends for astronomy during the past six years. In fact, in terms of purchasing power, the budget will be at its lowest level since the early 1960s, before construction of the 4-m telescope on Kitt Peak and of telescopes at CTIO had begun and prior to NSF assumption of responsibility for the solar facilities at Sacramento Peak in New Mexico. NOAO, which has already cut its staff by 12 percent since 1984 and by 150 people since 1979, will have to reduce staff by about ten more positions. At least one telescope at Kitt Peak National Observatory will be permanently closed; we are still determining whether or not other telescopes will be closed or additional programs terminated. The facilities will continue to deteriorate for lack of adequate maintenance. Instrumentation and computers will continue to be used long after they should be replaced with better technologies. Salaries in selected areas, including senior engineers, software personnel, and scientific staff, will remain uncompetitive with the universities with whom we compete for personnel. There is no funding to carry out the equivalent of NASA Phase A design studies of the telescope structure and enclosure for the 8-m telescopes.

Even with all of our telescopes in full operation, we are already forced to reject nearly two thirds of the requests we receive for observing time because we do not have enough facilities to meet the needs of the nation's astronomers.

Furthermore, we risk not even having the resources to observe and study the solar storms that are beginning to occur more and more frequently as we approach the maximum of solar activity, which is predicted to occur in 1991. These violent explosions and ejections of matter are not only of major significance for our understanding of stars and other plasmas throughout the universe, they directly impact our terrestrial environment with major consequences for the earth's ionosphere and upper atmosphere. We cannot afford to lose this opportunity to study what appears likely to be one of the largest solar maxima in recorded history. New work is essential during this maximum since the collaboration between plasma physics and solar physics holds bright promise for developing the capability of predicting solar storms.

The budget problems of NOAO are even more severe than Figure 2 implies since we have undertaken a major new program to measure the interior structure of the Sun. The experiment is known as the GONG (Global Oscillations Network Group) project, and its goal is to place six instruments around the globe to monitor the Sun continuously. The Sun is actually a pulsating star. Small regions on the Sun move alternately toward and away from us (Figure 3). These surface oscillations are generated deep in the interior of the Sun. By measuring the amplitudes (a few centimeters per second in velocity) and periods (typically a few minutes with 5 minutes being the most common) of the oscillations, it is possible to deduce what the interior structure of the Sun must be like, just as geologists infer the interior structure of the Earth by analyzing earthquakes.

This project, which involves more than 100 researchers throughout the United States and other countries, was the subject of a separate proposal that was submitted to the NSF, with an NOAO staff member as principal investigator. This proposal was very highly rated and was accepted, but it is obvious from Figure 2 that NOAO's budget has not been increased to support the GONG program. During FY 1989, $1,200,000 has been budgeted for the GONG project, and the remainder of the NOAO program has been cut to make room for this initiative.

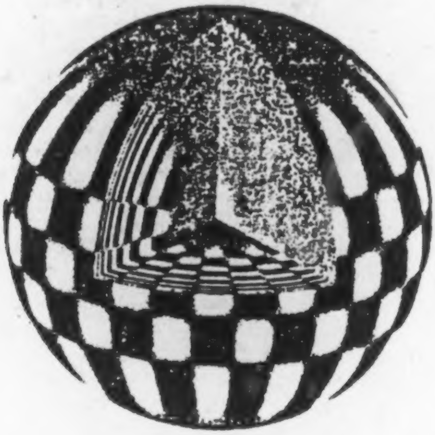


Figure 3. The surface of the Sun oscillates, moving alternately outward and inward. The dark areas in this diagram are moving toward the center of the Sun; the light areas are moving away from it. After about five minutes, the motions reverse. By analysing these motions, astronomers can determine the temperature, density, composition, rotation rate, and other characteristics of the interior of the Sun.

NSF has requested that we increase the funding for the GONG effort in FY 1990 to a total of $1,900,000. Since the total increase requested for NOAO for FY 1990 is only $1,000,000, and $700,000 of that increase must be committed to the GONG project, funding for the core program will once again fail to meet increases in costs due to inflation. If the GONG commitments are taken into account, the funding for operation of facilities has fallen by close to 20 percent over the seven year interval 1984-1990.

The problems faced by NOAO are not unique. Other national astronomy observatories have comparable problems and many excellent proposals for individual research grants to university faculty must be rejected solely because funding is not available.

It should be understood that the national observatories have no significant source of funding other than the NSF. As a matter of policy, NASA does not support groundbased follow-up observations in connection with astrophysics programs, although it does support some groundbased work in both solar and planetary research. This policy applies to private and university-based observatories as well as to the national centers.

Revitalization of Groundbased Astronomy

The collapse of the 300-foot dish at Green Bank stands as a symbol of the state of groundbased astronomy in the United States. While the collapse was apparently not directly caused by lack of funding for adequate maintenance, it does illustrate the fact that American astronomers must rely for their work on aging facilities that, while still highly productive, need to be upgraded or replaced in order for the U.S. to maintain scientific leadership in this field through the year 2000 and beyond. Only in radio interferometry, with the Very Large Array (VLA) and the Very Long Baseline Array (VLBA), which is now under construction, does the U.S. community have access to facilities that are clearly superior to those available elsewhere.

There has been much discussion about the desirability of replacing the 300-foot dish with a modern fully steerable antenna of comparable aperture. While I am not an expert in this field, I understand that the scientific justification for such a facility is very strong.

The scientific justification is at least comparably strong, in my view, for several other groundbased projects. There is a pressing need for larger optical telescopes, and there have been no new nationally accessible optical telescopes built in nearly 15 years. The VLBA should be finished as quickly as possible. The GONG project needs additional funding so that it can be completed in a timely and cost effective way. Upgrading the Arecibo radio telescope would greatly enhance its sensitivity.

There are plans to double funding for science through the NSF over the course of the next five years. ***If astronomy support were to increase at that same rate, then the funds would be available to carry out all of the projects mentioned here and would lead to a revitalization of several major fields of research.***

National Observatories and Science Education

Although astronomy is often thought of as the most basic of the sciences, astronomers receive broad training that permits them to contribute to research and development in many areas. Scientists with advanced degrees in astronomy are to be found in industry, where their contributions in such areas as detector development and image analysis draw directly on their astronomical training. Most astronomers develop substantial skills in developing complex software and often work for commercial firms that provide computer services to government and industry. Scientists who have developed the expertise in hydrodynamics and radiative processes to model astrophysical plasmas are making major contributions to the work of government weapons laboratories. The challenge of meeting the technical requirements of complex astronomical experiments has led to innovations in optics, detector technology, modelling the effects of the atmosphere on the imaging of distant sources, computer enhancement of images, and a host of other areas that have led to commercial applications.

The quality of science education in the United States has become a matter of increasing concern. Astronomy can make important contributions in this area. Many scientists in all fields trace their first interest in science to astronomy. Introductory astronomy is one of the most popular courses on college campuses and is often the only science course taken by non-science majors.

Most importantly in terms of education, the national observatories make available observing facilities that are open to all astronomers. Observing time is granted on the basis of peer review of proposals. It is therefore possible for any university prepared to invest in a small number of high quality faculty to have an excellent astronomy program. Many universities have taken advantage of this opportunity and have expanded their astronomy programs during the past decade. There are many campuses on which the astronomy program is the strongest of the physical sciences as measured by the quality of research. The existence of strong astronomy programs in turn raises the quality of the scientific programs in other sciences, particularly in physics, with which astronomy is often closely allied.

The national observatories also play an essential role in graduate education. Approximately one quarter of the astronomy Ph.D. dissertations in this country include data obtained at Kitt Peak, Cerro Tololo, or at the solar facilities operated by NOAO at Sacramento Peak in New Mexico. If work at the two national radio astronomy observatories is included, it is likely that more than half of the doctoral degrees granted in the U.S. in astronomy are based at least in part on data obtained at national centers.

The impact of the national centers is very widespread. In FY 1988, astronomers from 39 states and the District of Columbia made use of the facilities at NOAO (Table 3). Astronomy has succeeded in building strong programs of research and graduate student training throughout the nation because of past investments in national centers.

TABLE 3

HOME STATES OF NOAO VISITING OBSERVERS

Alabama
Arizona
Arkansas
California
Colorado
Connecticut
Delaware
Florida
Georgia
Hawaii
Illinois
Indiana
Iowa
Kansas
Kentucky
Louisiana
Maryland
Massachusetts
Michigan
Minnesota
Mississippi
Missouri
New Hampshire
New Jersey
New Mexico
New York
North Carolina
Oregon
Ohio
Oklahoma
Pennsylvania
Tennessee
Texas
Vermont
Virginia
Washington
Washington, DC
West Virginia
Wisconsin
Wyoming

Conclusion

Astronomy has been marked historically by major advances, often as a result of developments in theoretical physics or advances in technology, followed by periods of consolidation. Galileo's development of the astronomical telescope coupled with Newton's law of gravity, led to a complete description of the mechanics of the solar system. The development of the quantum theory and the construction of large reflecting telescopes in the early part of this century made it possible to obtain and interpret the spectra of stars and galaxies and determine their compositions and model their evolution.

The pace of discovery that characterized the first half of this century will accelerate during the next several decades. The opening up of the space windows, developments in particle physics, and the construction of a new generation of giant optical and infrared telescopes will permit astronomers to observe directly phenomena related to the evolutionary processes of stars, other solar systems, galaxies, and the universe itself.

The enormous opportunities in astrophysical research have been recognized by increased investments in space astronomy by NASA, the European Space Agency, and Japan, by expansion of university programs in astronomy throughout the U.S., and by an accelerated pace of construction of new groundbased facilities by the European nations and Japan. The recent pattern of contraction of funding for NSF-supported groundbased astronomy stands in stark contrast to the enhanced activity in other countries. If we in the U.S. are to continue to reap the full benefits of our investment in space astronomy, it is essential to revitalize the NSF groundbased astronomy program. The needs of groundbased astronomy could be met if the astronomy budget were to share proportionately from now on in the increase in the overall NSF budget that has been proposed for the next five years.

BIOGRAPHY

Sidney Carne Wolff

Sidney C. Wolff received her B.A. degree in Astronomy magna cum laude from Carleton College in Northfield, Minnesota in 1962 and her Ph.D. degree from the University of California at Berkeley in 1966. She also received an honorary D.Sc. from Carleton College in 1985.

After spending nine months in a post doctoral position at Lick Observatory at the University of California, Santa Cruz, Dr. Wolff joined the faculty of the Institute for Astronomy at the University of Hawaii in September, 1967. Hawaii was at that time beginning the development of an astronomical observatory at the summit of Mauna Kea, which at an altitude of nearly 13,700 feet is the highest mountain in the Hawaiian islands. Although there was considerable doubt at the time about the feasibility of operating complex observatories at so high an altitude (Mauna Kea remains the highest permanent astronomical observatory in the world), the pioneering work by University of Hawaii astronomers clearly established this site as the best in the world for optical and infrared astronomy. Mauna Kea now hosts more large telescopes than any other site.

After serving as Associate Director and as Acting Director of the Institute for Astronomy, Dr. Wolff accepted the position of Director of Kitt Peak National Observatory and Associate Director of the National Optical Astronomy Observatories in September, 1984. She thus became the first woman to head a major astronomical observatory in the United States. In August 1987 she was appointed Director of the National Optical Astronomy Observatories (NOAO), the organization responsible for operating the National Solar Observatory, Cerro Tololo Inter-American Observatory, and Kitt Peak National Observatory. Funds for operating these three observatories are provided by the National Science Foundation through a contract with the Association of Universities for Research in Astronomy (AURA), which also operates the Space Telescope Science Institute for NASA.

Dr. Wolff is best known for her research on stellar evolution, composition, activity, and atmospheric structure, and has published more than 70 technical papers and one book in her areas of specialization. She is also co-author of two of the textbooks most widely used in introductory astronomy courses at the college level and has recently completed the manuscript for a third text, which is designed to make the results of modern astronomy accessible to the non-scientist.

Mr. WALGREN. Thank you, Dr. Wolff.
Dr. Hagfors?

STATEMENT OF DR. TOR HAGFORS, DIRECTOR, NATIONAL ASTRONOMY AND IONOSPHERE CENTER

Dr. HAGFORS. Mr. Chairman, honorable Members of Congress, I am very grateful for this opportunity to testify on the questions posed by the subcommittee chairman in his letter of invitation of February 16.

The opportunity is particularly welcome in view of the crisis which has developed due to the current lean funding of astronomy. This crisis has been allowed to develop at a time when the rate of new discoveries and insights in astronomy is at a peak and the potential opportunities for further advancement in the field are brighter than ever.

Before proceeding to answering the questions, Mr. Chairman, I wish to caution you that the Arecibo Observatory, which we operate in Puerto Rico and which I represent, is different from our sister observatories. Although radio astronomy is our major program, we also do radar research. Such radar techniques are used both in solar system exploration and investigation of our atmosphere.

Whereas our radio astronomy activity is supported by the NSF Astronomy Division, the solar system radar program receives some support from NASA, and the atmospheric program, from the NSF Atmospheric Science Division. My personal research experience is primarily in the radar astronomy and the atmospheric sciences program.

Let me first address the first question you proposed, Mr. Chairman, objectives of the proposed NSF fiscal year 1990 astronomy research program. The objectives of the NSF astronomy program appear to be to continue as in the past with the funding of the three National Observatories and the grants program. For the grants program, there is a request for an increase above the level of the division, and for the three National Observatories, there is a request for an increase of only 3 percent, which amounts to a net decrease in operational funds.

This is a reflection of the overall funds available to the Astronomy Division, which, incidentally, is doing worse than the social sciences, as we heard earlier today. The increase for the Astronomy Division has been significantly slower than the allocation increase for the Foundation as a whole.

This continues a downward detrimental trend which has been going on for several years. I welcome the increase in the grants program above the level of the division. The research conducted at universities with student participation under this program is done better in this country than elsewhere, and is one of the most valuable assets of U.S. science. The lack of funds for the National Observatories, however, feeds back negatively into the university programs when the Observatories are unable to provide the observing facilities required by the grants recipients.

Let me now turn to the adequacy of support in the light of national and international effort. It is, in my opinion, unlikely that the United States can continue to play a leading role in every field of astronomy. I believe those fields should be pursued where the country can make a truly unique contribution. This is clearly the case with the Hubble telescope, with the VLA, the VLBA, and with the radio and radar astronomy programs in Arecibo.

In all of these cases, there is no serious international competition, not even on the horizon. It is quite clear all of these facilities will be in increasingly heavy demand with the ambitious plans for NASA to support one to two astrophysics missions per year and with the plans of the Japanese and the Europeans for accelerated activity in astronomy both in space and from the ground.

I am not sufficiently familiar with the situation in the optical wavelength region. There appear to me to be very good arguments for a new 8-meter telescope in the United States, but the case is somewhat clouded to an outsider when it is realized that 8-meter telescopes are being built or planned, one by the Japanese, four by the Europeans, in addition to privately financed telescopes of the same class in the United States, such as the Keck, and those of several university consortia. Means should be sought whereby NSF supports these efforts in return for some form of general access to the facilities by the astronomy community.

I believe there are good reasons for continuing technology development in radio and optical telescope design, and for pursuing such alternatives as optical interferometry with sophisticated image correction techniques. Failing such development, the United States will no longer be able to collaborate on the same level as our potential partners.

Let me now turn to the contribution of astronomy to the advancement of other fields.

My colleague from NRAO has produced in his deposition a splendid list of the impact of radio astronomy on the design of receiving systems, data recording, image restoration, et cetera. His comments apply equally well to the NAIL contribution.

I have also in my deposition made a fairly lengthy list of additional contributions, primarily in the radar field, that our astronomical activity has brought about.

I would, however, like to turn to the maybe most important contribution, in my opinion, of astronomy to other fields, and that comes from its educational role. There is a critical shortage of well-qualified young U.S. students in engineering, mathematics, and the physical sciences. In part, I believe this stems from a perception among young students that these fields are boring, uninspiring, and unexciting.

Astronomy has very high visibility—new astronomical discoveries appear in the press nearly every day—and has considerable public appeal. The Arecibo Observatory, for instance, receives as many as 60,000 public visitors per year. Astronomy does not appear to have the same stigma as engineering and the other physical sciences to students and may play a crucial role in enticing young students into engineering and the physical sciences fields.

Let me turn to the priorities for new astronomical research facilities. The question is rather broad in scope and will eventually, I believe, be answered by another of the decennium surveys conducted by the field of astronomy, which is coming up. The list of projects has been given, both by Dr. Vanden Bout and by Dr. Walker.

In my personal opinion—and it is probably somewhat tainted because I am part of the competition in this case for NSF funds for a particular program—but I believe that the highest priority must be attached to the completion and the placing into operation of the VLBA. This important program has been progressing much too slowly, making it more expensive than necessary, wasting the investment by keeping idle the partly completed facility.

I also believe that the GONG project ought to be given very high priority because it seems to me to be of extreme interest to astronomy, to study close-by stars the way it is being done.

NRAO has developed plans for a large-millimeter array. From an astronomical point of view, there is much to be recommended by such an enterprise, and I think that in the more distant future considerable weight should be given to that.

The Arecibo upgrade will provide very significant improvements in the performance of an already unique facility. There is no competition in sensitivity, and there is no evidence of any plan for a duplication of even the present performance of the telescope anywhere. There is enough interest in NASA, incidentally, in the planetary program and in the SETI community, for the upgraded Arecibo telescope for NASA to offer to pay half of the $20 million required to complete the upgrades.

For an investment by NSF of $10 million, it could ensure that a truly unique astronomical facility would remain so, at least through the end of this century. At the risk of sounding biased, I consider this the best bargain of all the facilities under consideration.

The 300-foot replacement is important to the community. U.S. astronomy has suffered a loss in observing opportunity as a result of the collapse. The full declination covered by the 300-foot cannot be observed by Arecibo, upgraded or not, and the loss of the 300-foot telescope leaves a void.

The planned 100-meter antenna will replace these capabilities and add many more, all worthwhile. My main concern is the cost of this telescope, which could have very important implications on the astronomy program.

Finally, a comment on the NSF research and educational program in astronomy. The NSF astronomy program is highly productive and effective, and the rate of new discoveries and realizations are steadily increasing as a result of new instrumentation, computers, and the hard work of astronomers. As a scientific discipline, astronomy has been highly successful, possibly more so than any other one.

The public's image of and interest in astronomy are very positive and vivid. Astronomy provides one of the most fertile fields for the education of students of engineering and the natural sciences, whether the student aims for a career in astronomy or not.

Yet, in spite of this success, the NSF astronomy budget has declined significantly in real terms over the last several years, and this in spite of a general increase in funding of the Foundation as a whole. Astronomers must consider themselves pariahs within the Foundation, and undeservedly so.

I end my deposition to this subcommittee by pleading for positive support for astronomy, which it deserves and needs.

Thanks again for this opportunity.

[The prepared statement of Dr. Hagfors follows:]

Statement by Tor Hagfors
Director, National Astronomy and Ionosphere Center

Mr Chairman, Honorable Members of the House

I am grateful for this opportunity to testify on the questions posed by Subcommittee Chairman Walgren in his letter of invitation of February 16. The opportunity is particularly welcome in view of the crisis which has developed due to the current lean funding of astronomy. This crisis has been allowed to develop at a time when the rate of new discoveries and insights in astronomy is at a peak and the potential opportunities for further advancement in the field are brighter than ever.

Before proceeding to answering the questions, Mr Chairman, I wish to caution you that the Arecibo Observatory, which we operate in Puerto Rico, and which I represent, is different from our sister observatories. Although radio astronomy is our major program, we are not always content to wait for photons created by nature to arrive, but create our own, send them toward bodies in our solar system, and watch for their return. Such radar techniques are used both in solar system exploration and in investigation of our own atmosphere. Whereas our radio astronomy activity is supported by the NSF Astronomy division, the solar system radar program receives some support from NASA, and the atmospheric program from the NSF Atmospheric Science Division. My personal research experience is primarily in the radar astronomy and the atmospheric sciences programs.

Objectives of the Proposed NSF FY 1990 Astronomy Research Program

The objectives of the NSF astronomy program appears to be to continue as in the past with the funding of the three national observatories and the grants program. For the grants program there is a request for an increase above the level for the Division, and for the three national observatories there is a request for an increase of three percent, which amounts to a net decrease in operational funds. This is a reflection of the overall funds available to the Astronomy division, which have been increasing at a significantly slower rate than the allocation increase for the Foundation as a whole. This continues a downward detrimental trend which has been going on for several years. I welcome the increase in the grants program. The research conducted at universities with student participation under this program is done better in this country than elsewhere, and is one of the most valuable assets of US science. The lack of funds for the National Observatories, however, feeds back negatively into the university programs when the observatories are unable to provide the observing facilities required by the grants recipients.

This scarcity of funds comes at a time when the opportunities for exciting research in astronomy are abundant. The search for those remnants of supernova explosions, pulsars continues, and objects whose properties were never anticipated are being found. Pulsars promise to provide tools for investigation of fundamental gravitational theories in physics, to provide time references and make available emitting sources allowing for new, unheard of investigations of the interstellar medium. It comes at a time when serious doubts have arisen about the mechanism of solar neutrino emissions. It comes at a time when there is a need to determine what makes up the 90 to 99% missing or invisible mass of the universe. It comes at a time when superclustering of galaxies are being observed and needs to be explained.

New instrumentation such as CCD detectors is becoming available, the Hubble telescope is about to be launched, the Magellan mission to Venus will be on the way soon, there will be infrared and X-ray telescopes available, and the Europeans, the Japanese and the Soviets are launching antennas for Very Long Baseline Interferometry from space, providing ever increasing angular resolution. The Very Long Baseline Array (VLBA) is slowly being completed, and the lack of operating funds for this wonderful and unique instrument is threatening its existence. The GONG project, which can have such consequences for our understanding of solar physics, is being completed at a snail's pace. The objectives for the Division should be to support a group of programs which are truly unique on a national and international scale.

The high activity in astronomy within NASA, with private US funding and abroad under government auspices will create a demand for astronomers to take advantage of the opportunities. NSF as the primary source of funding for the education of astronomers needs to be able to increase its support of astronomy. Now is not the time to decrease funding in this field.

Adequacy of Support in the Light of National and International Effort

It is unlikely that the US can continue to play a leading role in every field of astronomy. I believe those fields should be pursued where the country can make a truly unique contribution. This is clearly the case with the Hubble telescope, with the VLA and the VLBA and with the radio and radar astronomy programs in Arecibo. In all of these cases there is no serious international competition, not even on the horizon. It is quite clear that all of these facilities will be in increasingly heavy demand with the ambitious plans for NASA to support one to two astrophysics missions per year, and with the plans of the Japanese and the Europeans for accelerated activity in astronomy both in space and from the ground.
I am not sufficiently familiar with the situation in the optical wavelength region. There appears to be very good arguments for a new 8 m national telescope in the US, but the case is clouded to an outsider when it is realized that 8 m telescopes are being built or planned, one by the Japanese, four by the Europeans, in addition to privately financed telescopes of the same class in the US, such as the Keck, and those of several university consortia. Means should be sought whereby NSF support these efforts in return for some form of general access to the facilities by the astronomy community. I believe there are good reasons for continuing technology development in radio and optical telescope design, and for pursuing such alternatives as optical interferometry with sophisticated

image correction techniques. Failing such development the US will no longer be able to collaborate on the same level as our potential partners.

There may be advantages to much closer international cooperation in the construction of large and expensive astronomy facilities. The Europeans have taken the consequences of this, whereas the US, by and large, has shunned international cooperation for the construction of ground-based facilities. I believe that such cooperation should be vigorously encouraged in order to reduce the cost of meaningfully staying in the astronomy game. Some mechanism should also be sought for US participation in developing programs such as space VLBI.

Even with the savings that might accrue from international cooperative programs it is necessary to have realistic budgets which climb at least at the rate of inflation. If not, the US will not even be an attractive partner in international cooperation in astronomy.

NAIC has, together with the other observatories, experienced a steady decline in operating funds since 1984, see the Appendix for details. We have lost 15% of the staff, and have had to abandon activities such as the development of fast digital data-taking devices, and reduce to nearly zero the new development work on low noise receivers and antennas in order to be able to continue the day-to-day operation of the Observatory. This is extremely unfortunate, because it is under conditions of an immediate need for new technological development, such as is always the case in astronomy, that the necessary incentives exist for true innovation. The funds available for renewal of equipment have been so scarce in NAIC that some of the equipment in daily use is more than 25 years old, causing mirth in visitors from abroad, and melancholy in us who must live with it.

Contribution of Astronomy to the Advancement of other Fields

My colleague from NRAO has produced a splendid list of the impact of radio astronomy on the design of receiving systems, data recording, image restoration, time and frequency standards and remote sensing, and it serves little purpose to repeat any of his discussion. His comments certainly cover most of the NAIC contributions, and more.

I shall interpret astronomy, as it is practiced in Arecibo, in a wider sense to also include the radar investigations both of distant solar system bodies and of our own planet. A nonexhaustive list of contributions from this work, unique to Arecibo, to other fields follows:

- Tests of general relativity predictions from the rate of orbital slowdown in binary millisecond pulsars.

- Improvement in understanding of the properties, the geology and history of planetary surfaces, surfaces of satellites, asteroids and comets.

- Radar measurements of the absolute distances to the nearby planets enabled the successful targeting of the early planetary spacecraft.
- Radar mapping techniques developed for satellites and planets are identical to techniques used in sidelooking synthetic aperture radars.
- Techniques used in tomography were developed for the mapping of the lunar surface.
- Detection schemes developed in radar astronomy find application to ultrasonic measurements of flow patterns in blood vessels
- Radar observations of the moon and Mars were used in the selection of spacecraft landing sites.
- Observation of small scale space debris is being made in support of the Space Station Project.
- Radar observations of small earth-approaching asteroids provide the best means of precisely determining their orbits and assessing whether they pose any threat to our planet.
- Radar observations give data on the bulk composition of asteroids and is of importance in determining the feasibility of mining on asteroids.
- Radar observations of the dynamics of the troposphere and stratosphere helps determine diffusion rates and hence the speed of distribution of pollutants.
- Radar studies of induced ionospheric instabilities help us understand related instabilities in inertially confined laser fusion.

Maybe the most important contribution of astronomy to other fields I feel comes from its educational role. There is a critical shortage of well qualified young US students in engineering, mathematics and the physical sciences. In part I believe this stems from a perception among young students that these fields are boring, uninspiring and unexciting. Astronomy has a very high visibility, new astronomical data appear in the press nearly every day, and has considerable public appeal. The Arecibo Observatory, for instance, receives as many as 60,000. public visitors per year. Astronomy does not appear to have the same stigma as engineering and the other physical sciences, and may play a crucial role in enticing students into engineering and the physical sciences field.

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Priorities for new Astronomical Research Facilities

This question is rather broad in scope, and will eventually be answered by another of the surveys conducted by the field of astronomy every ten years. Among the projects which have been planned, proposed or are underway with the support of NSF are the 8 m optical telescope, the NRAO large mm array, the GONG, the Arecibo upgrades, the VLBA construction, and lately the 300' replacement. As I am clearly personally directly involved in the ranking of these projects, I must warn the committee members that my views may be tainted. This having been said, here are my personal views:

I believe the highest priority must be attached to the completion and the placing into operation of the VLBA. This important program has been progressing much too slowly making it more expensive than necessary, wasting the investment by keeping idle the partly completed facility. The question of operating funds for this facility looms and must be resolved by an increase in the Division funding. The VLBA, as currently conceived, will be a truly unique instrument. During the next 10 years similar instruments will probably be developed elsewhere as well.

Although the project is outside my field of competence, I believe that the GONG project is of extreme interest to astronomy, and that every effort should be made to complete it expeditiously.

I am a little more in doubt on the 8 m optical telescope, simply because such a national telescope will not be unique, in the US or internationally. I fail to see that it is impossible for NSF to buy into some private or foreign telescope consortium in order to acquire the partial use of a state of the art telescope in that class for the community. I also feel that NOAO should strive for a truly unique optical telescope at the cutting edge of technology, and that technical development to achieve this goal should be supported.

NRAO has developed plans for a large mm array. From an astronomical point of view there is much to recommend such an enterprise. There are two small mm arrays in existence already at Cal Tech and Berkeley. The Center for Astrophysics is building a mm array. The Japanese are expanding their mm array in Nobeyama, and IRAM is building such an array in Europe. If such a mm array is to be built, it is my belief that there ought to be consolidation in effort to ensure that there is little or no duplication and to make it possible to build a truly outstanding and unique facility, possibly with international cooperation.

The Arecibo upgrade will provide very significant improvements in the performance of an already unique facility. There is no competition in sensitivity, and there is no evidence of any plan for a duplication of even the present performance of the telescope anywhere. There is enough interest in the NASA planetary program and in the SETI community for the upgraded Arecibo for NASA to offer to pay half of the $20M required to complete the upgrades. For an investment by NSF of $10M it could ensure that a truly unique astronomical facility would remain so at least through the end of this century. At the risk of sounding biased I consider this the best bargain of all the facilities under consideration.

The 300' replacement is important to the community. US astronomy has suffered a loss in observing opportunities as a result of the collapse. The full declination range covered by the 300' cannot be observed by Arecibo, upgraded or not, and the loss of the 300' leaves a void. The planned 100 m antenna will replace these capabilities, and add many more, all well worthwhile. The cost of the replacement, $75M, is my main concern. If the funds required to construct, and to operate this telescope effectively come out of the NSF astronomy budget to the detriment of other programs, many of which will have to be killed, the priorities in astronomy will be set not by careful and considered discussions among astronomers, but by the freak accidental collapse of a telescope, and I would not be in favor. If, on the other hand, the funds for the 100 m are true add-ons to the astronomy program, then I wholeheartedly support the project.

Comment on the NSF Research and Educational Program in Astronomy

The NSF astronomy program is highly productive and effective, and the rate of new discoveries and realizations are steadily increasing as a result of new instrumentation, computers and the hard work of astronomers. As a scientific discipline astronomy has been highly successful, possibly more so than any other one. The public's image of and interest in astronomy are very positive and vivid. Astronomy provides one of the most fertile fields for the education of students of engineering and the natural sciences, whether the student aims for a career in astronomy or not. Yet, in spite of this success the NSF astronomy budgets have declined significantly in real terms over the last several years, and this in spite of a general increase in funding of the Foundation as a whole. Astronomers must consider themselves pariahs within the Foundation, and utterly undeservedly so.

I end my deposition to this subcommitte by pleading for the positive support for astronomy which it deserves and needs.

Thanks again for this opportunity to testify on behalf of the astronomy program.

Appendix

THE NATIONAL ASTRONOMY AND IONOSPHERE CENTER (NAIC)

THE ARECIBO OBSERVATORY, A PROFILE.

The Arecibo Observatory was completed 25 years ago. Originally conceived as an ionospheric observatory based on incoherent scatter technique it was soon realized that the Observatory also had great potential both as a radio and radar astronomy facility, and the necessary flexibility for astronomy observations was built into the telescope system from the beginning.

In 1970 the support of the Observatory was transferred from DOD to NSF and the current mode of operation as a National Observatory (NAIC) was established. At that time the original mesh reflector surface was replaced by 38,000 solid panels with nominal rms deviation from a sphere of 3.2 mm. An S-band 450 kW transmitter suitable for solar system radar astronomy was installed, and established the Observatory as preeminent in that field. The increased frequency coverage allowed for observations of neutral hydrogen and OH in our galaxy and in distant galaxies. The unrivalled sensitivity of the Observatory made it the major instrument in the world in many studies of hydrogen, OH and pulsars. The nearly explosive increase in users of the Observatory following the surface upgrading reflects the enormous increase in observational opportunities brought about by the increased frequency coverage. The observatory, used by 150 to 200 scientist annually, representing about 70 US and foreign institutions, operates 24 hours a day, 363 days per year. The typical distribution between the three research fields is 80% radio astronomy, 5% radar astronomy and 15% atmospheric science. A summer student program with 5 to 10 participants per year has been in operation since 1972. Typically five PhD's are awarded each year on the basis of observations made at Arecibo.

The telescope operates at 8 K/Jansky, six times the sensitivity of the now defunct NRAO 300' telescope. The system temperature is presently about 30 K. The beam can be steered to 20^0 from the zenith, permitting the tracking of celestial sources between declinations 0^0 and 40^0 for up to 2.5 hours. Sophisticated, but somewhat outdated, receiving and data taking equipment is available.

The users of Arecibo and the users of the NRAO 300' telescope come from the same scientific community. Although Arecibo does not cover the same declination range as the 300', we expect many of the past users of that telescope to redirect their research into projects which can be studied at Arecibo. It is, therefore, expected that the pressure for observing time at Arecibo will increase as a result of the demise of the 300'.

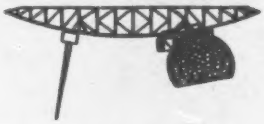
SOME CURRENT OPERATIONAL PROBLEMS.

The available operating funds have been in decline since 1984 (by 6% in current year currency). A large fraction of the operating costs are tied to relatively fixed operating costs, such as maintenance, power and communications, personnel and incremental costs. Hence, in spite of a staff reduction since 1984 of 15%, which has had serious detrimental impact on the support of visiting scientists, the funds for equipment and construction have been reduced to 3% of the operating budget. This does not allow NAIC to keep the equipment up to date, and the Observatory can no longer provide the instrumentation required to stay in the forefront of astronomy and atmospheric research and the situation is particularly embarrassing when European and Japanese scientists visit. Investment in equipment and construction should be at least 10% to keep the Observatory healthy. The scientific staff which was once as high as 20, has now been reduced to 13, and a much larger fraction of its time is now devoted to administrative tasks than ever before.

UPGRADING PLANS.

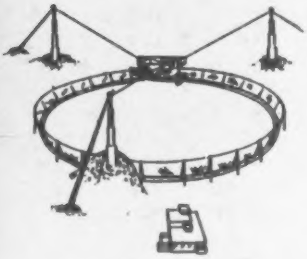
Encouraged by the 1984 funding increase NAIC began to develop plans for a major upgrading of the Observatory. A shield around the periphery of the main reflector was designed and a proposal was submitted to NSF. The net effect of this shield will be to substantially reduce the system noise of the telescope. A reflecting feed was also designed to replace the present "leaky waveguide" aberration correcting line feeds. The net effect of this new feed will be to increase the sensitivity from 8 to 12 K/Jansky, reduce the system noise from 30 to 20 K, increase instantaneous bandwidth from 50 MHz to several hundred and move the upper frequency limit from 3 GHz to 8 GHz. The increase in sensitivity of the solar system radar would be by a factor more than 50! (including a transmitter power doubling)

Proposals for the two projects have been submitted to NSF and have been pending for one to two years. NASA is sufficiently interested in both the radar astronomy and the SETI targeted search capability to have offered to supply 50% of the $20M required. No matching commitment has been made from NSF to proceed to the construction phase, and there is danger that this opportunity for a significant NASA infusion of funds into radio astronomy may be lost.

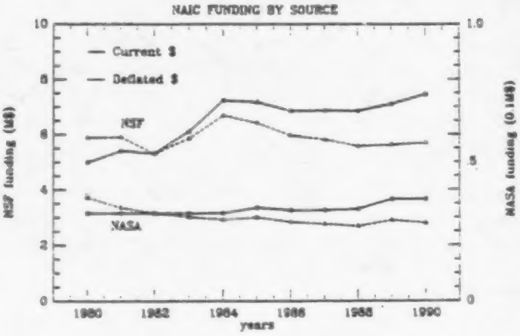


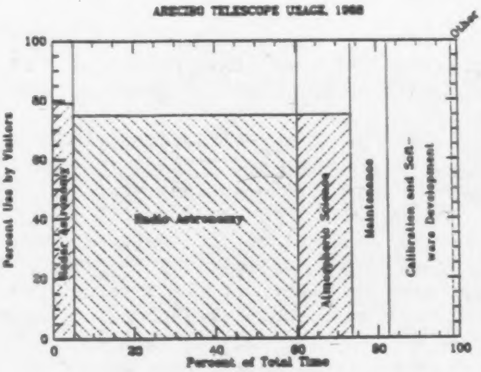
Phase 2. The Gregorian Subreflector

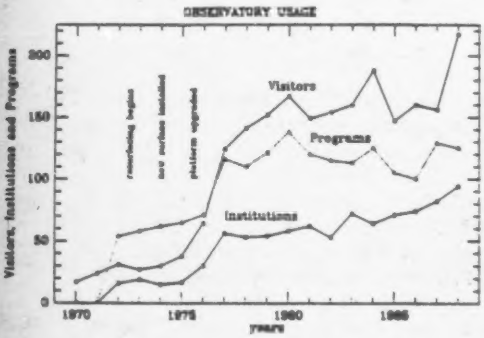
THE SECOND ARECIBO
UPGRADING PROGRAM



Phase 1. The Ground Screen







TOR HAGFORS

Biographical Notes.

Tor Hagfors was born in Oslo, Norway on December 18, 1930 and received a M. Eng. degree in Applied Physics with distinction from the Technical University of Norway in 1955. He received his Ph.D. in Physics from the University of Oslo in 1959.

From 1955 to 1959 and from 1961 to 1963 he was a scientist at the NDRE (Norwegian Defence Research Establishment). During the period 1959 to 1960 he was a Research Associate at Stanford University, California. From 1963 to 1967 and from 1969 to 1971 he was a staff member at the MIT Lincoln Laboratory, Massachusetts.

During 1967 to 1969 he was the Director of the Jicamarca Radio Observatory, Lima, Peru and during 1971 to 1973 he was the Director of the Arecibo Observatory, Arecibo, Puerto Rico. From 1973 to 1982 he was Professor of Electrical Engineering at the University of Trondheim. From 1976 he was also the first Director of the European Incoherent Scatter Association (EISCAT), an organization created by six European research councils for the purpose of conducting auroral research by radar in northern Scandinavia. During the 1980-1981 academic year he was at the Max Planck Institute for Aeronomy in the Federal Republic of Germany.

In 1982 he was appointed Director of the National Astronomy and Ionosphere Center and joined the faculty of the School of Electrical Engineering and the Department of Astronomy of Cornell University.

Dr Hagfors has published nearly 80 scientific papers on plasma physics, communication theory, antenna engineering, ionospheric physics, radar astronomy and radio astronomy and is the coauthor of two books.

He is a member of the American Astronomical Union, the American Geophysical Union, a Fellow of the Institute of Electrical and Electronics Engineers, a member of the International Union for Radio Science, and a number of European professional societies. He was awarded the van der Pol Gold Medal by the URSI General Assembly in July 1987 for his major contributions to radar engineering and the theory and experimental development of the incoherent scatter technique, and for his work as director of some of the world's largest facilities used for incoherent scatter observations. In 1989 he received the von Humboldt award from the von Humboldt Foundation.

Mr. **Walgren**. Thank you, Dr. Hagfors.

I guess what is going through my mind is, it seems to be a nice case study of how construction projects can occupy more and more of a field, and that point has been raised with respect to the larger science programs that we engage in. To see astronomers feel like they are pariahs within the NSF may be a forerunner of what the rest of science will have to feel like when it comes up and butts heads with the superconductor, supercollider, and other large construction budgets.

Let me ask for comments on the international-American cooperation potential. Dr. Wolff, you are advocating the priority of new domestic optical systems, as I understand it, and one of the reasons you do that is because they are doing a lot of that in Europe and elsewhere. And yet you contrast that with the areas where they may not be doing things elsewhere that perhaps we can.

How should we approach that? Should we be saying, because they are doing that, we want to join them, or because they are doing it, we want to do more of it ourselves? What is the right response?

Dr. **Wolff**. Well, I think that there are certain facilities that are such basic tools that American astronomers must have access, whether they are unique or not. The next frontier for ground-based optical astronomy is 8-meter telescopes. For technical reasons, that is probably the maximum limiting size for single telescopes.

The efforts that NASA is making in space will realize the full potential only if we have access to ground-based telescopes to follow up on those observations. From observations in x-rays, for example, alone, you cannot even tell whether you are looking at a star or a galaxy. And so, in order to understand and interpret the x-ray measurements that NASA will make, we must be able to observe very faint sources, and that implies a need for very large optical telescopes.

Therefore, I think we must have access to them. On the other hand, given the funding history for astronomy over the last 7 years, I cannot be very optimistic that the NSF is going to make an investment in optical telescopes that is comparable to what has been made in Europe.

We have, however, been encouraged by Mr. Bloch to seek international partners for at least partial funding of a project involving two 8-meter telescopes, one in the northern hemisphere and one in the southern hemisphere. That would given us an advantage over the European efforts, where there is access to only a single hemisphere. He is working with us to try to bring about such a partnership with the United Kingdom and with Canada. I cannot tell, ultimately, whether we will be successful or not, but I think it is an important way to get started, with the United States providing only part of the funding.

I think that the growth path for optical astronomy is to use multiple telescopes together on a single site. So if we get started this way, and if it turns out that we can build optical and infrared interferometers, as we have already built radio interferometers, then there would be the possibility of expanding to an array of optical telescopes. But this seems to me an effective way to get started on building an essential tool.

Mr. **Walgren**. So there is no down side to the international cooperation and joint effort in that area?

Dr. **Wolff**. I think that there is a certain amount of administrative overhead in terms of working with another country, but at this point I see it as the best solution.

Mr. **Walgren**. I see.

The Chair recognizes the gentleman from Iowa, Mr. Nagle.

Mr. **Nagle**. I want to do something that is patently unfair, and I apologize for it, but I am trying to get a link because, as I was commenting to staff, I sometimes feel like Thomas More on his way into the court when he was the King's conscience. He was the equity judge for the King, and people would hand him gifts as he tried to get into the King's court so as to get dispensation for their particular son or daughter.

I sit up here and I hear, frankly, group after group come in and ask for more money for funding and research, and I appreciate that, and I have been historically generally supportive. I am not antagonistic to what you are saying.

But let me take you back a week ago, if I can, and cite for you the testimony of Ernest L. Boyer, who is the president of the Carnegie Foundation. In just a small quote from him, he says, "The harsh truth is that science and mathematics education in the Nation's schools is in sad shape."

From a second witness at that hearing, a Dr. Bell, Professor of Chemistry at Simons College, he said, "Why has college-level science education tended to be overlooked instead of neglected, according to several major studies, including the University of California study in 1987? The reason is that undergraduate education comes in second on almost everyone's list of concerns."

Now, I could cite you from the Carnegie study report after report after report that says that if we are looking to the future of astronomy and research in astronomy, you are not going to have the students or the mathematicians or the scientists in 2000 if we build every facility that we should.

I am kind of curious about your response to the concerns that we are hearing consistently from most panels about undergraduate and pre-K-to-12 science/math education in this country, and how does your request for funding address what has to be an overriding national concern on your specific projects?

Dr. **Walker**. I think astronomers are particularly active in undergraduate education. Almost all of us who are at universities teach courses to undergraduates, in particular to undergraduates who are just introducing themselves to science.

I think, also, most of the National Observatories have research programs oriented toward young people. Several years ago, I participated in a program at Kitt Peak National Observatory. It was a program oriented toward students from disadvantaged minority groups, introducing them to science. One of the young men in that program eventually applied to our program in applied physics at Stanford and is about to get his Ph.D. in quantum electronics.

So I think that astronomy really has an important role to play in attracting young people into science and introducing them to science, and this is something which is very important to astronomers. Many astronomers are involved in the development of facilities for undergraduate use. We have an undergraduate observatory at Stanford which allows students to carry out astronomical research projects as part of their course work.

Mr. Nagle. Dr. Walker, I don't mean to be unfair, but let me quote your own testimony back to you, if I can, from page 10: "The research supported by the Division of Astronomical Sciences at the National Centers and at the universities is very closely linked to graduate education. Support for graduate students, especially in the final years of study, comes mainly from NSF or NSF grants. It is important to realize that graduate astronomy training is very broad and highly technical. Astronomy Ph.D.'s work in a variety of situations," et cetera, et cetera.

It seems to me the focus of your testimony was on graduate education, and again, I don't mean to be harsh, but I am concerned about this because—are the reports that we are getting right, that there is an absence of competent future scientists coming forward to address the field of astronomy?

Dr. Walker. Well, I think, in the case of astronomy, we still have more students who are applying to our programs in graduate education than we can handle. I think the problem is more serious in engineering, where so many of our graduate students are actually foreign students, and now many of those students are returning to their own countries to seek opportunities there.

So we are really running into a great deficit of manpower. It is not so much a problem in astronomy, I think, as it is in engineering and other areas of physical science, but I do maintain, although I did not necessarily emphasize it in my prepared remarks, that astronomy has a very important role to play in undergraduate education, and I think most astronomers take that role very seriously.

Mr. Nagle. Most people tell us, if you talk to undergraduate college professors—and we have had a number of them here in years past before the panel—that they feel that one of the reasons that we are not moving people through undergraduate to Ph.D. level of achievement in the course of their study is that most of the research is done, frankly, at the graduate level, that there is a lack of research opportunities among undergraduates. Is that true in the field of astronomy?

Dr. Walker. Well, again, we do have some opportunities for undergraduates to do research in astronomy. Astronomy is very nice in that regard because we can in fact have students who are not necessarily highly technically trained do experimental research in astronomy with small telescopes, and we have taken advantage of that at Stanford, and many other institutions have a similar program that provides students with an opportunity to do undergraduate research.

I recently visited Princeton for the review of a Science Foundation proposal there, and they also, at Princeton, have a very active program of involvement of undergraduates in astronomical research. The same thing is true at Caltech. So many of the research projects which are supported by the Foundation do employ undergraduates as research assistants as well as graduate students.

Mr. Nagle. So you would say that, in your judgment, NSF's grants—undergraduate versus graduate—are in proper proportion at the present time?

Dr. **Walker**. Well, many of the grants to support undergraduate education are channeled through other areas of the Foundation, although they are reviewed, I think, within the astronomy program. I would say there is a good balance between undergraduate and graduate emphasis in most astronomy programs in the country.

Mr. **Nagle**. And if there is an adequate balance, is there adequate funding for the number of grants that are being sought in both fields?

Dr. **Walker**. I cannot say that I have any hard data on the rate at which grants are funded to contrast undergraduate-focused grants and graduates. I cannot answer your question directly. But I do think that it is important to have available more funding to support undergraduate education in astronomy. There is not enough, I think, in terms of supporting development of facilities at universities, and I think that is an area which could indeed be improved.

Mr. **Nagle**. Does anybody else want to comment?

Dr. Wolff and then Dr. Vanden Bout.

Dr. **Wolff**. If I could make a few comments, in this country, every year, there are 180,000 students in junior colleges and colleges that take an introductory astronomy course. Now, most of those people, of course, do not go on to be professional astronomers. I think many of them do go on to be professional scientists.

I have a letter here from Ken Wilcox, who writes—and you will find out who he is—

> As president of the Astronomical League, I represent over 10,300 amateur astronomers throughout the U.S., and as a research chemist for Phillips Petroleum Company, I owe my career in polymer chemistry to astronomy. There is no branch of science that offers greater appeal to young Americans to pursue a technical or scientific career.

[A copy of the letter mentioned above follows:]

ASTRONOMICAL LEAGUE

A FEDERATION OF ASTRONOMICAL SOCIETIES
A NON-PROFIT ORGANIZATION

- *To promote the science of astronomy.*
- *To encourage and coordinate activities of amateur astronomical societies.*
- *To foster observational and computational work, and craftsmanship opportunities in the various fields of astronomy.*
- *To provide a medium for correlating amateur activities with professional research.*

SCIENCE SERVICE BUILDING
WASHINGTON D.C. 20036

Please reply to:

Ken Willcox, President
225 S.E. Fenway Place
Bartlesville, OK 74006

March 2, 1989

Doug Walgren
2241 Rayburn House Office Bldg.
Washington, D. C. 20515-3818

Dear Congressman Walgren,

As President of the Astronomical League, I represent over 10,300 amateur astronomers throughout the U. S., and as a research chemist for Phillips Petroleum Company, I owe my career in polymer chemistry to astronomy. There is no branch of science that offers greater appeal to young Americans to pursue a technical or scientific career. Having had the opportunity to discover the universe at an early age, I realized that there were many areas of science that interested me. This experience is shared by many of my fellow amateur astronomers and illustrates that astronomy's impact reaches far beyond the traditional astronomical community. We share observational results with them, and we consider ourselves part of the broader community of astronomers. It is our desire that you consider the outstanding and unusual breadth, depth, and effectiveness of astronomy's impact on education and science in your deliberations on the future of NSF support for groundbased astronomy at our national centers and universities. Without adequate financial support for observational astronomy, the emphasis we so desperately need for science education in our country will suffer further defeat.

Phillips Petroleum Company sponsors an annual science teachers workshop for over 300 elementary and secondary science teachers that addresses every area of science. Each year, the one subject more teachers show interest in than any other is astronomy. They intuitively know that by understanding this subject better, they can attract the students that would most likely choose a career in science. Most high school students and many college students do not know what they want to be because they have not had the opportunity to discover the fascination of the universe. By lending support to astronomical research, our government will provide the necessary foundation on which our country can grow technologically.

The greatest benefit is without doubt to our nation's young people who, right now, more than ever before in the history of our nation, need something to focus their attention on rather than drugs and TV. None of us can save the world singlehandedly, but by offering alternatives to our young people such as astronomy, which has such an appeal, I intend to save as many as the good Lord will allow me.

Sincerely,

Ken Willcox

I think that many scientists will say that the first science that attracted them was astronomy.

I would also like to underscore what Art says, and that is that many of us do take undergraduate education very seriously. As director of a National Observatory, I do not teach, but 40,000 of those students in the last 2 years have used a textbook that I co-authored, and so I think we really do try to make astronomy attractive to undergraduates.

Dr. VANDEN BOUT. I can answer the specific question with respect to NRAO on undergraduate involvement in research opportunities. We, along with the other National Centers, run a summer program that brings undergraduates to the observatory for a research experience. We have typically 200 to 250 applicants, and we have funds to support 20.

If we had more money, we could handle more, but there is a limit to that. That is, if that program alone were funded so, say, 50 students could come to the Observatory, the Observatory as it is presently staffed would have difficulty coping with that many students and giving them a meaningful summer research program experience. It comes together.

On the other subject you mentioned earlier, I would say that the reports are correct, that the demographics indicate that in 10, 15 years there will be a shortage of scientists and engineers in the country, and we should be working on correcting that, I think. But the correction has to come at many levels.

Mr. NAGLE. I guess I am curious, then. If there is a consensus of the panel that, yes, there is going to be this crisis in math, science, and engineering people within the country, but, because of the attractiveness of astronomy, you will be exempt from that crisis?

Dr. VANDEN BOUT. No, I don't think we will. I don't think we will.

Mr. NAGLE. Then what recommendations, if this group were going to look beyond the specific project requests that we get from every group, legitimate project requests——

Dr. VANDEN BOUT. Sure.

Mr. NAGLE. I don't mean to diminish it. But if a member of this panel were interested in trying to see that you had an astronomer, say, in the year 2000 that was qualified, what recommendations would you make in terms of our funding and our allocations?

Dr. VANDEN BOUT. I think that in the year 2000, those students are sort of entering college now; that is, if they are going to emerge with a doctorate in astronomy in 2000, these are sort of senior high school students now.

I think what they have to see is that there is opportunity in astronomy. There is certainly interest in the field. They can see that just from casual reading. Programs that emphasize and make available opportunities for undergraduates to get involved are important, I think. But I believe, when they get serious about picking a discipline and deciding if they are going to go to graduate school, and so forth, they want to know that when they emerge from that there is an opportunity to do something.

I don't think that, at least in ground-based astronomy right now, they see that opportunity. They see instead, when they read Sky and Telescope, they see stories about troubles at the observatory, and it is discouraging to them.

I think the undergraduates that come to NRAO for the summer have a good research experience. They find out a lot about what doing astronomy is really like, and that is positive. At the same time, they cannot help but see that there are problems at the observatory, and that is not going to be encouraging in the long run.

So I would urge that focus not be placed just in one part of the program. It is a long process to bring students from, say, their high school years to their careers, and it requires a sustained effort over a long period of time to do that. I think the fact that the Foundation has put funds into undergraduate research opportunities is good, but it is not enough.

Mr. NAGLE. Anybody else? Yes?

Dr. HAGFORS. I can support Paul Vanden Bout's statements about the success of the undergraduate programs—summer programs—we run. In Arecibo we have a similar situation. We have funds for about eight undergraduates. We have about 100 applicants for these slots.

Now, I am not completely certain that we could accommodate all that many more in the program simply because the staff is very depleted at Arecibo, and we cannot ask the staff to take care of more than one or two students and educate them. So, really, if we were to do more in educating undergraduates, we would really have to have a somewhat larger staff and be set up for it in a better way.

Now, this program, it turns out, does, of course, emphasize astronomy, and it entices people, young students, to go into natural sciences, and it turns out, if you look at these students a few years down the road, you will find that maybe as much as 50 percent of them have gone into other fields, usually in natural sciences. I know one example of one of the students who went into law, but that is very exceptional.

So I do think that undergraduate programs like the programs we run do serve a very useful purpose in encouraging students to go into science and engineering.

Mr. NAGLE. I know the Chairman wants to move on, but let me just say, if I can—and when I talk undergraduate, in deference to the Chairman, I also mean community colleges and junior colleges and 2-year institutions, which are, of course, the lifeblood of the educational system in this country.

But to me this country is like a deer in the deep of winter living off the fat of the fall. We have tried in the fifties and the sixties, and as we move forward into the year 2000, the group that we educated is aging, and we are not replacing them. Every study that we have indicates that we are not competing adequately or training adequately compared to our foreign competitors.

I think that, whether your field is astronomy or whether your field is physics or whether your field is chemistry or engineering, it is almost a duty of the current profession of scientists to push this Congress and push this administration to see that we start correcting the deficiencies that we have in the educational system in this country in these fields.

Again, I did not mean my questions to be hostile, but I am concerned about it.

I thank the indulgence of the chairman.

Mr. **Walgren**. Thank you very much, Mr. Nagle, for that focus in the record.

How do you feel about the hearing that you get at NSF? Dr. Walker, you are the Chairman of the Advisory Board. Do they have a comprehensive approach that you have confidence in that would relate these operations cutbacks to new construction increases and in some way that you have confidence in their conclusions?

Dr. **Walker**. Well, I am afraid that I will have to say that we simply have a disagreement with the highest levels of the NSF management on this issue. We believe that the basic funding that astronomy is getting is insufficient. We have made that point, and I think that we have had a fair hearing. I am afraid, unfortunately, that our point of view has not prevailed, and I do not understand the mechanisms in detail of how these allocations are made, and I presume that the National Science Board is the ultimate authority for making these——

Mr. **Walgren**. Have they been involved in this at this point?

Dr. **Walker**. Well, I believe there have been presentations to the National Science Board, but it is my impression that the Science Board has not chosen to suggest alterations in the basic allocation of resources up until this point. I believe that Dr. Wolff recently made a presentation, so she may be in a position to comment on their role in this process.

But I think that we have been able to make our views clear to the advisory committee, and we do meet with Mr. Bloch and Dr. Nicholson from time to time to discuss the priorities, and I think we have made our point very clear that the current level of funding for the ongoing research and basic support programs of the division is simply inadequate.

Mr. **Walgren**. But, to the best of your knowledge, they have not responded with a comprehensive plan or approach or set of principles that they are using to allocate their investment?

Dr. **Walker**. No. Well, I think the response has been that there are many very high priorities within the Foundation, and that astronomy may have to reconsider its priorities. But I believe that astronomy—and I think Mr. Bloch would probably agree with this—has done at least as good a job, and perhaps a better job, than any of the other disciplines in ordering its priorities.

We do have the annual decade surveys, as Dr. Vanden Bout has pointed out. We have closed down older facilities. In fact, recently there was a report evaluating the priorities of radio observatories in the country, and as part of that, the committee looked at facilities which have been shut down. There have been about a dozen radiotelescopes, some at the National Observatories, some at universities, shut down over the last decade-and-a-half.

Mr. **Walgren**. So has NSF followed the general structure of priority-setting that the discipline has internally pursued?

Dr. **Walker**. Well, as I tried to make clear in my remarks, there were two areas of priorities that the Field Committee identified. One was the construction of new facilities, and in that regard, the

Foundation has followed those recommendations as far as the funding available will go, but the funding has been insufficient, so that two of the important priorities, particularly the construction of a large optical telescope, have simply not been possible because of the limited funds.

In the second area, the area of the basic prerequisites to carry out research, including support of young investigators, development of new technologies, and so forth, maintenance of facilities, the funding has simply been inadequate because of the very large decrease in the effective amount of funds available. We have made this point to the Foundation, and there is no other solution except to either shut down one of our absolutely indispensable facilities or to have more funds available.

I think we are getting close to the point where a very fundamental decision will have to be made, because I think each of these Directors—and I must confess my admiration for the difficult task they have had to deal with—each of them, I think, has cut back his or her operations to the bone, and there is no room, literally, for any further reductions without major closures of facilities which are absolutely indispensable to us.

Mr. WALGREN. Are there other comments? Would anyone else like to respond to that area?

Dr. Vanden Bout?

Dr. VANDEN BOUT. I am unaware of any formulated, articulated plan that would explain why the budgets in astronomy have been so low over the last 5 years. On the other hand, the pattern is there, so one assumes that there is some rationale for this, but I have not been able to uncover it.

In asking for an explanation of a new year's budget, each year there is a different reason. The first year there is a problem with this, and the next year, well, somebody has to be last; not everybody wins. The next year, there is some reorganization and the budget was overlooked, and so forth.

But I have found really no rationale that could be articulated for this, and after 5 years, one assumes that there must be one.

Mr. WALGREN. Is there feeling that it is because of the commercial thrust of NSF under Mr. Bloch's direction, which is responsive to many of the directions that Members of Congress and, I am sure, people in the administration would like him to persue but it is away from basic research and certainly away from non-applicable research in a commercial sense?

Dr. VANDEN BOUT. It is possible; that is, our situation is shared by physics, chemistry, the sort of core basic sciences in the Foundation. We are not unique in this, although I think we have been near the bottom more often than the others.

The explanation may be just as simple as the Foundation wants to do some things, and the budget can only accommodate them if other things suffer.

Mr. WALGREN. All right.

Dr. Hagfors, you said at some point that the United States has been reluctant to enter into international arrangements with respect to ground-based facilities. Is there a pattern there that stands out? And what is the basis of that reluctance on our part?

Dr. **Hagfors**. It is very difficult for me to say exactly what the reason for that is, but I am actually speaking as one with very considerable experience in international cooperation in research projects.

I actually started a research project in Europe with six national science foundations involved as funding agencies involved, and it was relatively successful as a scientific enterprise.

I quite agree that the overhead in international cooperation is somewhat higher than it would be in a national program. But, on the other hand, if this is the only way you can get such a venture funded, then I feel that that is the way to go.

I feel that in some cases there may have been lost opportunities in some of the enterprises which are now on the way, like the VLBA. I personally feel that U.S. scientists should have worked harder in order to get Canada involved to build a few of the telescopes. It did not happen for various reasons that I have been told, but, nevertheless, I think that there was an opportunity there that could have saved the project some funds.

I am sure there are other opportunities, like in the millimeter array venture that will come up. We see that the Japanese are building an array at a site where they probably should not build a millimeter array because the climatic conditions are not right for it.

The United States has many such sites that could be used, and maybe we could get a few antennas from Mitsubishi or somewhere in order to reduce the cost somewhat and still get a top-notch array that way. It is my perception that this has not been pursued vigorously enough.

Mr. **Walgren**. I see.

Dr. Vanden Bout?

Dr. **Vanden Bout**. If I could respond to that, I will say that we are interested in international cooperation with respect to the millimeter array, and Tor is quite right about the Japanese project being at an unsuitable site. They are not willing, however, to discuss this until their optical project is well in order and under way, and they proceed at a very deliberate pace. So I see that as a future opportunity.

With respect to VLBA, there was an opportunity to do something with Canada which did not work out, mainly because the Canadian astronomers wanted to build an array of their own. When that failed, it produced a sort of vacuum of opportunity. It could not be picked up as a joint thing again. So it did not work out. If we had worked harder, maybe earlier, to convince them that a joint array was the way to go rather than an independent array, we might have made some progress there.

VLBI—that is, very long baseline interferometry science—is very international, and we expect that the VLBA will be used about one-third of the time in combination with antennas all around the world. The Italians are building an array. There are important antennas in Europe and in Japan and Australia. And so the observing program will, for a significant amount of the time, be a joint effort.

There are also space ventures in very long baseline interferometry science. The Soviet Union has a mission called Quasat, and the Japanese have one called VSOP. We expect to participate in both of those missions if things work out.

Mr. **Walgren**. I see.

Let me, on behalf of the committee, express our appreciation to you.

Let me ask one other thing. How is it again that you know the light is 10 billion years old? What are the mechanics of that again?

Dr. **Wolff**. Well, what happens is that you have to measure the distance to this galaxy.

Mr. **Walgren**. I see.

Dr. **Wolff**. It is complicated how you do that, since it is so faint. But, basically, the whole universe is expanding, and by measuring the velocity of the expansion, you can tell how far away the object is. So we know that it is so far away, it takes 10 billion years for the light to get from there to here.

Mr. **Walgren**. And you get the distance by measuring the shift in the light rays?

Dr. **Wolff**. The rate at which it is moving away from us.

Mr. **Walgren**. And that gives you the rate at which it is moving away, and you can extrapolate from it.

Dr. **Wolff**. It turns out that the rate at which an object moves away from us is proportional to its distance from us, and so by measuring that rate, that velocity, we can—and it is moving at about 93 percent the speed of light.

Mr. **Walgren**. And why is it proportional to the rate that it is moving? Why is it moving faster out there than the ones closer?

Dr. **Wolff**. That is complicated, and it helps to have a picture, or I could send you my textbook. [Laughter.]

But the universe is expanding at a uniform rate, and so that turns out that every distance will double in the same period of time. So the things that are further away, for that distance to double, they have to be moving faster than the ones that are nearby, because you can double that distance by moving not so fast.

Mr. **Walgren**. I see.

Dr. **Wolff**. It turns out that if you work it all out, it comes out that the distance is proportional to the speed with which things move away. And, of course, we think that things are moving away because, in the beginning, everything was concentrated at a very tiny volume, and then it began to expand, the so-called "big bang," and it has been expanding uniformly ever since for about 13 billion years. And so we date the beginning of that expansion as the beginning of the universe. But we are trying to get a good handle on really what the number is.

Mr. **Walgren**. What do you think the chances are of any view of the universe discrediting the original big bang at this point? Is it possible that there are phenomena out there that would tell us that, well, that is right, they are moving away from the center, but there is another reason for that other than they all originated at one point 13 billion years ago?

Dr. **Wolff**. People are starting to explore some alternatives, because there are a few observations that cannot be explained by the standard big bang model. But those people are in the minority right now, and almost everything we see can be explained by this standard version.

Mr. **Walgren**. I see.

Dr. **Wolff**. And so, at least after the first second or so, if you can believe this, of the universe, I think that the explanation is going to hold. But the details of what happened in that first second may actually change profoundly.

And then, of course, there are things we do not understand, and they may hold vital clues that we are now missing. You know, it is when you think you understand a science that you are probably in the biggest trouble.

Mr. **Walgren**. Well, all right.

Thank you all very much. We appreciate your spending this time with us this morning, and we hope we can encourage support for your interests in our process.

Let's then turn to the last two witnesses, Robert Craig from Keystone Center and Bruce Manheim from the Environmental Defense Fund, talking about the Antarctic.

I would invite our former Congressman McCormick to join us if he wants to. How are you, Mike? Nice to see you. If you have any special interest—well, I don't want to say it that way. If you have particular interest, come join us sometime up here.

Mr. **McCormick**. Thank you. I will.

Mr. **Walgren**. All right, great.

Your written statements will be reproduced in the record, so please feel free, particularly at this time of the day, to focus on points you would like to make that would then stand out from the reproduction of your written comments in the record.

Shall we go in the order in which I introduced you to the record and start with Mr. Craig, or would you rather a different order? Suit yourself.

STATEMENT OF ROBERT W. CRAIG, PRESIDENT, THE KEYSTONE CENTER

Mr. **Craig**. Thank you, Mr. Chairman, and thank you for providing me with this opportunity to comment.

I should say, as I tried to in my written remarks, that it was a great opportunity and privilege to serve on the Antarctic Safety Review Panel. I hope that some of the work that we did in that relatively short period of time has proved useful in terms of focusing on things that need to be done in Antarctica.

The work of the panel was basically to assess the overall safety problems that we undertook to examine in Antarctica. What we found was a clear degree of connectedness between a great many safety issues and sound environmental protection. We also discovered that much of what has happened in the past was due to the earlier conflicting character of joint civilian and quasi-military operations by the United States on the continent.

I say this not as a criticism but really as just an observation of what in fact happened. It is probably in the nature of the events that took place down in Antarctica at that time. I don't think that a civilian enterprise probably would have successfully gone forward in the way that the initial research was undertaken without the kind of support provided by the Naval Air Squadron, BXE-6, working in cooperation with the National Science Foundation. But the lines of responsibility and communication were not clearly defined, and as a consequence, many things literally fell between the cracks.

It was the Safety Panel's impression that the basic problems of command and control in Antarctica are being addressed and that the new definitions of authority and responsibility will allow for and ensure not only that the overall safety goals set by the panel but the needs of environmental cleanup and management will be fulfilled, providing certain other steps are taken. I would like to comment on a few of those elements more specifically.

I found the National Science Foundation Department of Polar Programs Initiative to be generally a very positive step forward. It has a number of areas which must be more specifically defined. A number of recommendations for actions must be prioritized. Among these, I believe, is a clearly stated critical path approach for the removal and elimination of hazardous and solid waste. This must be undertaken in a systematic fashion rather than piecemeal.

To a certain degree, the retrograding of hazardous and solid waste from Antarctica has already begun, but it must become an annual commitment, and I believe my colleague, Dr. Manheim, has referred to that in his report.

I am concerned about waste water discharges and the proposed remediation as outlined in the initiative. I believe what will be undertaken will prove to be inadequate. The numbers of personnel and the concentration of discharge into the waters adjacent to McMurdo base and the need to fulfill our NEPA requirements simply require a more state-of the-art approach. This will cost more to install, and it will require more to maintain and operate.

I believe that hazardous waste must be managed in Antarctica on a systematic basis and that a waste management plan must be developed at the earliest possible moment. Similarly, incineration technology should be selected and put in place at the earliest moment.

Atmospheric emissions must also be controlled. The long-term implications for doing good science, not to mention fundamental environmental and moral responsibility for the preservation of the pristine character of Antarctica, requires this. It, too, will cost more, but it can be done.

With respect to Antarctica, I am in complete agreement with Dr. Bruce Manheim. I am troubled by the growing impact of tourism on the Antarctic environment. It may well be that if we truly agree with the framework of international agreements on wildlife in Antarctica, an effective discipline for tourism is already in place. It may not receive favor from the tour groups and tourists themselves, but it could ensure boundary conditions that will not be exceeded.

Overall, as I have hinted in my prepared remarks, I am pleased that NSF has undertaken the initiative in what I hope is a reaction to our Safety Review Panel report, but I am also concerned that what needs to be done and can be done with the proposed funding may fall short. Perhaps only time, 2 or 3 years out, will tell what we can get done, and a reassessment at that time may give us a more valid sense of what, for the long run, will be needed to fulfill our environmental and safety obligations in Antarctica.

Thank you again for letting me make this presentation.

[The prepared statement of Mr. Craig follows:]

The following is my formal statement to the Subcommittee on Science, Research & Technology in preparation for my testimony as a witness before the Subcommittee.

I am Robert Craig. I am President of the Keystone Center in Keystone, Colorado. The Center is a not-for-profit science and public policy institution which works on a wide variety of national environmental, health, natural resource and technical regulatory issues.

I was privileged to be a member of the National Science Foundation Panel on Safety in Antarctica in 1987 and 1988. The charge to the Panel was to examine all aspects of safety involving U.S. personnel in Antarctica and to make recommendations on any and all aspects of U.S. operations in Antarctica. The Panel was represented by a wide diversity of experience in a variety of hostile environments, by extensive management responsibility, and by considerable environmental protection experience.

One panel member was at the time the Admiral in charge of Air Safety for the United States Navy; another had headed one of the nation's leading research institutions and had previously been a general in the U.S. Army; a female member of the panel was a senior Vice President of General Motors, a physicist and an expert in environmental protection; the Dean of Graduate Studies of a prestigious Agriculture and Science University was also a panel member, as was the former Dean of the Harvard University's School of Public Health. The Chairman of the panel was a former astronaut and Chairman of the California Energy Commission. I have sometimes reflected in the face of the distinguished aforementioned assemblage how I was made a member of the Panel. My own background includes over 50 years of mountaineering on several continents, including a number of expeditions to the Himalayas and experience in the Arctic. The Center I head and of which I am the founder, is deeply involved in national, environmental and science and technology issues, particularly involving hazardous waste, clean air and clean water issues and biotechnology regulation policy (including AIDS vaccine liability.) My own training has been in biology and philosophy of science and the better part of my life has been spent in getting thoughtful people to work toward consensus on difficult policy issues.

My experience of the extremes of discomfort, deprivation, and cold at high altitude and in the Arctic and the demands and difficulties of technical mountaineering in a variety of places notwithstanding; the character and magnitude of the Antarctic environment, its extreme variations in temperature and wind, its vastness, its inhospitality and its constant threat of danger and its staggering, lonely beauty make it unique of all places on the earth. I offer this expression of respect for the Antarctic environment as I endeavor to comment on the Safety, Environment/Health Initiative.

Chairman Walgren of the Committee has asked for my comments for the NSF's environment/health/safety initiative as presented in the fiscal year 1990 budget. I have read the Initiative carefully and I believe, overall, it is consistent with the findings and recommendations of the United States Antarctic Panel (USAP).

With respect to the Chairman's question, "Is the NSF plan consistent . . . with proposed international guidelines for the environmental protection of Antarctica?", it is my impression that the NSF approach outlined in the Initiative is consistent with the Waste Disposal Code put forth by the Scientific Committee on Antarctic Research last fall in Hobart, Australia.

So far as time and resource application are concerned, it is my impression that five years and $100 million to get the job done will place very considerable demands on the agency and will require real ingenuity if NSF is to also fulfill its scientific missions, not to mention the adequate maintenance of the U.S. presence in Antarctica. Nevertheless, I believe this is a significant beginning and one that I, as a Panel member, am surprised and pleased to find is being given such serious consideration.

When considering operations, the conduct of scientific investigation and research and issues of safety, environment and health in the Antarctic one must constantly keep in mind the uniqueness I referred to above. To achieve safe and healthful operations in that extreme and harsh place the issues of safety and health are inseparable from sound environmental management. It may sound simplistic, but I would like to assure the Committee that a safe environment is a clean environment. From that axiom flows the recommendations contained in the Safety Review Panel

Report. I believe the Panel agreed unanimously that attitude of mind applies broadly to a variety of safety and health issues from aircraft maintenance and procedures to base operations in McMurdo, Palmer and South Pole Stations and from remote campsites in the interior to the maintenance and operations of vessels in waters of the Antarctic. It applies as well to the morale of personnel in every corner of every U.S. facility in Antarctica. By cleanliness is not meant an excessive concern for neatness or fastidiousness, but a sense of knowing where everything one needs and uses is, and a recognition that hostile environments, especially Antarctica, require a sense of healthful respect and self discipline if one is to function effectively and safely.

With respect to specific elements of the Initiative pertaining to environmental clean-up and waste management I believe NSF has proposed creative and achievable targets and taken careful cognizance of the recommendations of the Safety Review Panel. I would like to stress that plans for land filling the Winter Quarters Bay Dumpsite should not be considered as a final solution until an environmental engineering assessment is concluded as to the stability of the hazardous wastes in the site. This assessment could take the monitoring data the Agency intends to generate over time along with whatever best available technology can be brought to bear on evaluating the site over a five, ten and fifteen year period. It may e determined that while total removal will never be attempted, that routine and thorough monitoring of the site and its wastes will be necessary into the forceable future.

I strongly recommend the NSF consider the implications of the U.S. Navy's new management and disposal of plastics at sea agreement made with a number of environmental organizations in 1988. The question of plastics in the environment of Antarctica is a serious and complicated issue and not one that will necessarily be solved by total avoidance, though a policy of minimization should be pursued. One of the most essential morale factors of personnel operating in Antarctica is the quality of diet and variety and character of food prepared in the stationary bases and for those who must operate remotely in the field. The use of plastics must weigh against fulfilling sustaining and pleasing diets and the retrograde and/or destruction of plastics must be assured for those which are determined to be necessary.

SAFETY AND HEALTH

I believe NSF has responded well to the recommendations concerning safety and health in Antarctica. Much needs to be done and it is hoped that all of the elements outlined in the Initiative will be pursued on parallel and concurrent critical paths under the oversight of the Director of Polar Programs. Virtually all of the recommendations of the Safety Review Panel assume that the NSF will obtain the services of a Safety Environment and Health Officer (SEHO). This high level, enormously responsible position will require a person of rare talent, but the success of the Safety/Health/Environment Initiative simply requires a commitment to finding the best possible man or woman for the job. If any criticism might be made of the otherwise thorough and responsive Initiative it is that this vital position is not clearly cited and the role of the SEHO) is not strongly articulated.

To assure that the role of the Safety Environment and Health Officer is made part of the record I offer the following from the Safety Review Panel Report:

SAFETY, ENVIRONMENT AND HEALTH

As the Panel conducted its review of USAP activities in which safety is a direct issue, it was impressed by both the diversity of concerns and their interaction with the related topics of environment and health. This impression subsequently led the Panel to utilize a broad definition of safety including related environment and health issues in conducting its investigations and preparing its recommendations.

It should be understood that while the Panel was favorably impressed by virtually everyone's genuine concern for safety, the existing institutional design does not reflect this concern.

Managing the Responsibility

To effectively manage overall responsibility for safety in the USAP, dedicated attention must be given to this issue. The current division of responsibility for safety between the USN and NSF (via its support contractor) does not place adequate attention on the assurance of a comprehensive safety program. If no one is in charge, then no one is held accountable to see that all safety issues are addressed. When an issue "falls between the cracks" there is a tendency to either point in the other direction or to simply let it lie there. It is difficult to apply the MOA's intention to any specific unaddressed or ambiguous issue unless it is currently causing immediate and urgent concern.

Moreover, DPP has not designated anyone with the responsibility and authority to develop, implement and enforce a comprehensive set of policies, guidelines and regulations for program-wide safety.

Mindful of this urgent need, the Panel recommends that the Division of Polar Programs establish a full-time Safety, Environment and Health Officer (SEHO) who reports directly to the Director, Division of Polar Programs (MGT-4).

We also recommend that the SEHO establish and the Division of Polar Programs adopt a comprehensive set of safety, environment and health (SEH) standards for use by and within the U.S. Antarctic Program. These standards should mimic and adopt by reference, to the extent feasible in the U.S. Antarctic Program environment, existing national standards and practices (MGT-5).

The Panel also considered the inherent difficulty in assuring the effectiveness of SEH standards in a high pressure operational environment. There is such a wide diversity of USAP activity during the austral summer and the pressure to squeeze just a bit more out of everyone and everything before the season closes is so high that effective enforcement of the SEH standards is necessary in order to assure compliance. Therefore, the Panel recommends that the SEHO be empowered to issue citations for violations of the safety, environment and health standards. Administrative hearings and sanctions are recommended as tools for enforcing the adopted safety, environment and health standards. All citations and subsequent actions should require the attention of the Director, Division of Polar Programs and the National Science Foundation Director (MGT-6).

Finally, recognizing the extremely important, eve dominant role played by the prime support contractor and its employees, the Panel recommends that the National Science Foundation should incorporate an incentive clause for safety, environment and health performance into the prime support contract for the U.S. Antarctic Program. Annual goals should be negotiated between the National Science Foundation and the contractor to serve as the basis for rewards or penalties. (MGT-7).

SEHO Support

As the Panel began formulating formal recommendations, it became clear that a large portion of the work involved in implementing them would fall to the SEHO. We also realized that much of the work required is "front end loaded", i.e., there will be an intensive initial effort required to formulate and adopt the necessary guidelines, standards and work required once the standards are in place should demand a lower level of effort. Recognizing this high initial workload to establish the standards, we recommend that the SEHO be provided contractor support to accomplish his or her assigned tasks. Contractor support of these tasks must be totally separate from the U.S. Antarctic Program prime support contractor in order to avoid real and/or perceived conflict of interest (MGT-8).

Interface with CNSFA and the Operations Support Contractor

While top level responsibility for safety remains with NSF, the day-to-day implementation of safe practices and procedures will be the responsibility of the major supporting organizations, i.e., the NSFA and the operations support contractor (currently ITT/ANS). The Panel assumes that the SEHO will establish a close working relationship with the safety officers of these two organizations. Such a relationship could include the formation of a standing safety committee or the equivalent. It is essential that the SEHO establish clear lines of responsibility and delegate operational authority for safety within the areas of program responsibility assigned to these two organizations.

To assure there is no confusion as the expectation for responsiveness on the part of the civilian work force to SEH standards the Panel recommends that the operations support contractor be obliged within the terms of its contract to comply with the adopted safety environment and health standards and any subsequent revisions thereto (MGT-9).

Since the current contract with ITT/ANS is terminating and the contract is open for bids, the Panel feels it is essential that NSF amend the contract Request For Proposal (RFP) to specify apprise potential bidders of obligations they would be expected to meet regarding the SEH standards.

U.S. Navy Interface

It is clear that the USN interface needs to be carefully worked out, respecting the legitimacy of both NSF oversight and the existing USN safety system. The Panel realizes that the USN safety process, especially the flight safety system, is well established ans integrates decades of operational experience. Nevertheless, there are adaptations necessary for the antarctic and the customization of procedures should be coordinated with the SEHO. Additionally, there are many interfaces between NSFA and the support contractor where boundary conditions need matching and negotiation. Environmental, construction, electrical and their codes and standards may differ slightly and create unnecessary conflict if not coordinated.

Regarding the general topic of flight safety, the Panel does not specify how NSF and the USN should provide SEHO oversight, but it emphasizes that oversight must be provided. This recommendation should not be interpreted as supporting in any way an intrusion into the USN flying safety procedures per se. The Panel does not support or advise direct management of the VXE 6 day-to-day operational decision process. The Panel supports assigning to the operational level both the authority and responsibility for safe operations while maintaining top level oversight to see that this delegation is properly executed according to established procedures.

Therefore, the Panel recommends that the National Science Foundation should negotiate with the U.S. Navy and incorporate within a revised memorandum of agreement the means whereby the safety, environment and health standards and their enforcement will be affected within U.S. Antarctic Program responsibilities assigned to the U.S. Navy. If otherwise applicable U.S. Navy regulations, practices or standards are less stringent than those adopted for the U.S. Antarctic Program, the U.S. Antarctic Program safety, environment and health standards should apply in practice (MGT-10).

Individual Responsibility

In practice, safety comes down t the individual. Many factors contribute to safe performance on the part of individuals, including training, skill, attention, attitude, judgment, experience, and other factors. Some of these factors are addressed elsewhere in this report. However, in most cases, a necessary prerequisite to good performance is knowledge of what is expected.

Therefore, the Panel recommends that a safety code of conduct for U.S. Antarctic Program participants be compiled and issued to each individual in the program regardless of affiliation. This code of conduct should be prepared under the direction of the SEHO and should reflect the adopted safety, environment and health standards and policies of the USAP as they apply to the individual (MGT-11).

With regard to the final comments on the Initiative with regard to Increase To Base Budget, I am in strong agreement that these items deserve support and that they justify an increase in the operating costs of the USAP.

Finally, I would like to note that I am mindful of strong criticism of NSF's operating procedures and scientific mission activities by persons and organizations concerned with the preservation of Antarctica's pristine environment. That much needs to be done in Antarctica is evidenced by the Safety Review Panel's fairly detailed and I believe carefully reasoned Report.

I believe our recommendations provide NSF with a baseline from which the agency, given time, funding and a firm commitment can much more effectively begin to assure environmental preservation and management in Antarctica. Thank you.

Respectfully submitted,

Robert W. Craig

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Mr. Walgren. Thank you, Mr. Craig. I appreciate that very much.

Mr. Manheim?

STATEMENT OF BRUCE S. MANHEIM, JR., ATTORNEY AND SCIENTIST, ENVIRONMENTAL DEFENSE FUND

Mr. Manheim. Thank you, Mr. Chairman.

I appreciate the opportunity to appear today on the subject, a very important subject, of environmental practices observed by the National Science Foundation at U.S. research bases in Antarctica.

This hearing, indeed, marks the first time in more than a decade that Congress has seriously considered this very important issue. It has now become clear, in light of a number of reports, including this very valuable Safety Panel report produced by NSF, that a number of nations operating in the Antarctic, including the United States, have failed to reduce pollution from research bases or to minimize impacts to Antarctic wildlife.

Indeed, the environmental practices of the National Science Foundation, the Federal agency responsible for U.S. scientific research in Antarctica, we believe, would not be permitted anywhere in the United States. For that reason, we welcome NSF's recent initiative, which calls for $5 million over the course of fiscal year 1990 and $30 million for the next 5 years to address these environmental problems.

However, as my fellow panelist, Mr. Craig, has pointed out, I think quite correctly, the initiative falls short. And we believe it should be revised, expanded, and expedited, so that not only does it meet its own stated objectives but it also addresses the full range of environmental practices and impacts caused by U.S. activities in Antarctica.

Specifically, NSF's initiative, I think, is important for at least four reasons. First, scientific research is having an increasingly significant impact on Antarctic wildlife. The loss of more than 50,000 Adelie penguins at the Cape Hallett base, which was formerly jointly operated by the United States and New Zealand, as a result of scientific research, is simply one of many examples of that problem.

Secondly, sound environmental practices at U.S. research bases and other bases in the Antarctic ultimately will protect important scientific research that is taking place there. We had a very good reminder of that axiom just in January with the shipwreck of the *Bahia Paraiso,* the spillage of literally thousands of gallons of diesel fuel, the loss of several sensitive breeding rookeries, and, more importantly, the loss of perhaps up to 25 years of scientific research at Palmer Station.

Third, these impacts on the environment and research are likely to increase as the growing number of nations interested in Antarctica's potentially vast resources turn their attention to the continent. Indeed, for a nation to have voting status under the various agreements that govern Antarctica, it must first conduct a, "substantial scientific research activity" in Antarctica. That essentially is translated into establishing a base there. There are now 16 nations that have acceded to the treaty, and several, if not many, of them may soon develop bases in Antarctica.

Finally, the importance of the NSF initiative is heightened by these very recent international efforts that are underway to strengthen guidelines governing waste disposal and other environmental impacts in Antarctica. Indeed, if NSF were to adopt strict controls on U.S. activities and their waste disposal problems, then State Department diplomats will be in a much stronger position to press for more comprehensive environmental protection controls when the rather antiquated 1975 Antarctic Treaty Code of Conduct on Waste Disposal comes up for revision in October in Paris later this year.

As NSF pointed out in its 1980 programmatic environmental impact statement, perhaps the most significant impact from the U.S. Antarctic program in Antarctica is just simply the addition of foreign materials to that pristine environment. More than 2,000 tons of cargo and up to 7 million gallons of petroleum products are shipped there each year. Unfortunately, virtually all of these materials have been essentially left there as pollutants. For example, untreated sanitary wastes, very likely containing toxic chemicals, are discharged into Antarctic waters. Combustible solid wastes are burned in open pits with no emissions controls whatsoever. Noncombustible solid wastes have been bulldozed into an open refuse pit or onto annual sea ice. Hazardous wastes are used to ignite open-pit burns, and diesel fuel-powered generators release particulate emissions without any controls whatsoever.

Not only would those actions, were they to be undertaken in the United States, violate U.S. laws such as the Clean Air Act or Clean Water Act, the Resource Conservation and Recovery Act, but indeed, they even contravene the much less rigid international rules that have been set up to govern waste disposal in Antarctica.

For example, the 1964 Agreed Measures required all nations, including the United States, to take all reasonable steps to reduce pollution of waters adjacent to the coast. Yet, because U.S. disposal practices, some of which were by the Navy, contributed to this problem, bottom sediments in the waters near McMurdo Station, in terms of PCB and heavy metal concentrations, are more polluted than virtually any waterways in the United States.

Moreover, NSF has consistently failed to observe those laws that do clearly apply to Antarctica. That includes a 1978 executive order issued by President Carter, Executive Order 12088, that requires the agency to comply at a minimum with the 1975 Antarctic Treaty Code of Conduct on Waste Disposal. It also includes the Antarctic Conservation Act, which also was passed in 1978, and mandated NSF to establish a pollution control program. Unfortunately, a decade later, that pollution control program still does not exist.

To be brief, I would just like to endorse many of the remarks that were made by Mr. Craig. We, too, are disappointed that NSF's initiative does not satisfactorily address waste water discharges. There are a number of nations in Antarctica that will do a better job, even if NSF is successful in obtaining money and implementing what it proposes to do as far as waste water discharges. These include Poland and Brazil, which reportedly treat their sewage at research stations, and apparently reduce it to secondary treatment levels.

The Scientific Committee on Antarctic Research recently recommended certain types of technology that U.S. research stations should adopt in Antarctica to address that problem, and we believe NSF should heed those admonitions.

As far as solid waste disposal goes, we have serious concerns about NSF's continued plans, apparently, to maintain a landfill at McMurdo base. That landfill has been there since 1980 despite a 1975 Code of Conduct international prohibition on landfills in Antarctica. Indeed, NSF now apparently proposes to establish yet another landfill at McMurdo with the burial or rather covering over of possibiy hazardous wastes at the Winter Quarters Base site.

We believe that solid wastes, particularly noncombustible solid wastes, hazardous wastes, chemical wastes, combustion ash, and even in some cases solid wastes that are combustible must be removed from Antarctica. This should certainly be the highest priority of the National Science Foundation.

It is not technologically impossible to do that. In fact, 50 percent of the nations that currently operate in the Antarctic do undertake these so-called retrograding activities, and in fact NSF successfully took back more than 1.7 kilograms of materials last year. So this is something that we believe should be pursued on an annual basis.

Atmospheric emissions are yet another problem. There are basically two sources, one from the diesel fuel generators that are used to provide energy to research bases there. In fact, ironically enough, the power generators that are used at McMurdo base are required to control their emissions in the most heavily polluted parts of the United States; yet there are no controls on these generators in perhaps the most pristine atmosphere in the world.

Moreover, open-pit burning of combustible wastes is another serious source of air pollution in the Antarctic. Not only does it threaten terrestrial lichens up to miles away but also has apparently interfered with certain atmospheric studies that are taking place at that station and other stations.

Australia, Brazil, Korea, and several other nations have installed controlled incinerators; there is no reason that the United States cannot, also.

The initiative does call for a design of an incinerator at McMurdo, but that leaves open the notion that this open-pit burning will continue at Palmer base and also, to a lesser extent, South Pole station. We cannot endorse that, nor can the National Science Foundation.

And finally, just to be very brief, there are two other places that NSF initiative should be expanded. One is in terms of essentially establishing a more effective enforcement mechanism to protect Antarctic wildlife in protected areas, and also to establish a mechanism to monitor and assess environmental impacts from U.S. activities in Antarctica.

Let me stop now because of time, and I would be happy to welcome any questions.

[The prepared statement of Mr. Manheim follows:]

STATEMENT

OF

BRUCE S. MANHEIM, JR.
ATTORNEY AND SCIENTIST
ENVIRONMENTAL DEFENSE FUND

BEFORE THE

SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY

OF THE

HOUSE COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY

ON THE

ENVIRONMENTAL PRACTICES

OF THE

NATIONAL SCIENCE FOUNDATION IN ANTARCTICA

MARCH 14, 1989

Mr. Chairman and Members of the Subcommittee:

Thank you for the invitation to appear before the Subcommittee on the subject of environmental protection practices followed by the United States at its scientific research bases in Antarctica. This hearing marks the first time in more than a decade that Congress has seriously considered this important issue. It has now become clear that a number of nations operating in Antarctica, including the United States, have failed to reduce pollution from research bases and to minimize impacts to Antarctic wildlife. Indeed, the environmental practices of the National Science Foundation (NSF) -- the federal agency responsible for U.S. scientific research in Antarctica -- would not be permitted anywhere in the United States. For that reason, we welcome NSF's recent initiative which calls for $5 million for FY 1990 and $30 million for the next five years to address these environmental problems. We believe, however, that NSF's proposal must be revised, expanded and expedited so that it meets its stated objectives and addresses the full range of environmental impacts caused by U.S. activities in Antarctica.

I. BACKGROUND: IMPORTANCE OF THE NSF ENVIRONMENTAL INITIATIVE

With the adoption of the Antarctic Treaty in 1959, international scientific research in Antarctica has flourished. Today, more than 50 bases operated by 22 nations have been established on the continent. Because Antarctica derives much of its scientific value from its relatively uncontaminated condition, it is rather ironic that the day-to-day operation of these bases is currently the major source of pollution there. Three recent reports have recently focused attention on environmental impacts from the four bases that the U.S. maintains in Antarctica: "On Thin Ice: The Failure of the National Science Foundation to Protect Antarctica" by the Environmental Defense Fund (EDF); NSF's "Environmental Protection Agenda," and "Safety in Antarctica" by NSF's Safety Review Panel. As a result of these efforts and the widespread publicity they received, there is strong public support for improvement of environmental practices at these installations (see attached editorials). There are at least four reasons for these views.

First, scientific research bases in Antarctica are having an increasingly significant impact on Antarctic wildlife. Although the Antarctic ice sheet is virtually barren of terrestrial life, small ice-free areas along the coast and nutrient rich waters surrounding the continent provide essential habitat for myriad penguins, seals and other marine species. It is within these fragile areas, which only constitute 1-2% of the continent, that scientific bases have been established. As a result, Antarctic marine life must inevitably compete with research installations for limited breeding areas. The loss of more than 50,000 Adelie penguins in just nine years from construction and operation of

Cape Hallett base by the United States and New Zealand makes clear that the fragile Antarctic environment generally is losing the battle.

Second, sound environmental practices at research bases in Antarctica will ultimately protect vitally important scientific research taking place there. Indeed, retaining Antarctica's pristine condition is critical if the continent is to serve as a useful scientific laboratory and as a baseline standard for monitoring global atmospheric processes such as stratospheric ozone depletion and global climate change. Currently, untreated sewage discharges and toxic wastes foul the waters of this laboratory, while emissions from power generators and open pit burns contaminate its atmosphere. The sinking of the Bahia Paraiso -- the Argentine research supply ship that spilled thousands of gallons of oil near Palmer station in January -- demonstrates the importance of protecting the environment so that scientific research can also be preserved.

Third, these impacts on the environment and research are bound to increase as the global community turns its attention to exploiting Antarctica's potentially vast living and non-living resources. Indeed, nations will first look to small ice-free areas along the Antarctic coastline to establish research bases. That is because a nation must "conduct a substantial scientific research activity" in Antarctica before it can achieve voting status under the Antarctic Treaty. Nations that have recently developed bases and become voting members include China, Uruguay, India, Brazil, Spain, and Sweden. Last year, Peru withdrew its application for membership since it did not maintain a base. This year, Peru established a research base but its supply ship, the Humboldt, ran into rocks on departing from Antarctica. The subsequent oil slick portends the serious impacts that may occur when, and if, the 16 other nations that have acceded to the Treaty develop bases in Antarctica.

Finally, this issue is significant because international efforts are currently underway to strengthen guidelines governing waste disposal and other environmental impacts in Antarctica. In 1987, the Antarctic Treaty parties adopted new procedures to assess environmental impacts. Later this year, the parties will consider a report by the Scientific Committee on Antarctic Research (SCAR) that recommends revisions to the Code of Conduct on Waste Disposal adopted by the Antarctic Treaty parties in 1975. Clearly, if NSF were to adopt strict controls that address environmental pollution in Antarctica, then the United States would be in a much stronger position to press for more comprehensive environmental protection when the Code of Conduct comes up for revision. Indeed, this is particularly important since McMurdo base with its 1500 inhabitants accounts for almost half of all Antarctic summer residents.

The Foundation has declared that the purpose of its initiative is to "clean up debris from past operations, and to bring present operations into agreement with current regulations, prevailing attitudes, and current technology." Unfortunately, NSF has not set out a detailed time scale for implementation of this initiative nor has it identified relative priorities or costs of particular projects. As a result, we have analyzed NSF's initiative in light of the requirements of domestic environmental laws and the recommendations contained within SCAR's recent report. At the same time, we have focused on other nations' efforts in Antarctica to ascertain precisely what can be done. These actions demonstrate that strict pollution control methods are technologically possible in Antarctica and that the United States should follow their example. To that end, our testimony evaluates the extent to which NSF's initiative will (1) reduce pollution from research bases; (2) prevent impacts to Antarctic wildlife and protected areas; and (3) include assessment and monitoring of environmental impacts.

II. REDUCING POLLUTION FROM SCIENTIFIC RESEARCH ACTIVITIES

As pointed out by NSF in 1980, perhaps the greatest environmental impact of the U.S. Antarctic Program is the addition of foreign materials to a pristine environment. Each year, more than 2000 tons of cargo and 7 million gallons of petroleum products are shipped to U.S. bases in Antarctica.

Until very recently, virtually all of these materials were ultimately left behind as pollutants in Antarctica. Indeed, although NSF has recently stepped up its efforts to remove accrued wastes from the continent, its current practices still result in significant pollution. For example, untreated sanitary wastes that very likely contain toxic chemicals are discharged into Antarctic waters; combustible solid wastes are burned in open pits with no emission controls whatsoever; non-combustible solid wastes are bull-dozed into an open refuse pit; hazardous wastes are used to ignite open pit burns; and diesel-fueled power generators release particulate emissions without any controls.

Unfortunately, certain of these actions have contravened international rules governing waste disposal in Antarctica. For example, the 1964 Agreed Measures for the Conservation of Antarctic Fauna and Flora require all parties to "take all reasonable steps towards the alleviation of pollution of waters adjacent to the coast and ice shelves." Yet, until 1986, the U.S. routinely bull-dozed garbage, possibly including hazardous wastes, onto annual sea ice near McMurdo Station. As the ice melted, this debris sank into and polluted waters near the station. Indeed, a 1983 NSF study demonstrated that bottom sediments in the waters near McMurdo are more heavily polluted in terms of PCB (polychlorinated biphenyl) and heavy metal (lead and cadmium) concentrations than virtually all estuaries and bays in the United States. The U.S. has also failed to observe the 1975

Treaty Code of Conduct on Waste Disposal in at least three ways. These violations include discharging untreated sanitary wastes without maceration, maintaining a landfill at McMurdo base, and discarding plastics into that landfill.

These practices are particularly troubling in light of Executive Order 12088 and Section 6 of the Antarctic Conservation Act. The former requires NSF to comply with "environmental pollution control standards of general applicability" in Antarctica. Although NSF concluded in the early 1980's that the Code of Conduct contained those standards, it has failed to observe them. Moreover, NSF has ignored procedural requirements under the Order, including periodic consultation with the Environmental Protection Agency (EPA). As to compliance with the Antarctic Conservation Act, NSF has been equally remiss. That 1978 statute directed NSF to issue regulations that identify pollutants in Antarctica and to specify measures controlling such discharges. Unfortunately, those regulations have never been promulgated and the pollution control program that Congress envisaged for Antarctica more than a decade ago has never been realized.

The Foundation must strictly observe these requirements if the U.S. is to have any hand in addressing the serious record of non-compliance with the Code recently documented by SCAR's special panel of experts on waste disposal. Their draft report found that 60% of Antarctic bases burn chemical wastes in open pits rather treating or removing them from the Treaty area. Moreover, almost 75% of all bases maintain open burns with no emissions monitoring or controls at all. Despite those findings, the SCAR report also makes clear that a number of nations are doing a better job of protecting Antarctica than the United States. Drawing on the experience of these nations, the panel recommended revisions that would significantly strengthen the 1975 Code of Conduct. Most significantly, it suggested that national environmental standards should at a minimum be observed in Antarctica. Unfortunately, NSF's initiative would neither implement many of SCAR's important recommendations nor would it satisfy national standards in controlling wastewater discharges, solid wastes, hazardous wastes, and atmospheric emissions.

A. WASTEWATER DISCHARGES

For the past 30 years, both McMurdo and Palmer Stations -- the U.S. coastal stations in Antarctica -- have discharged untreated raw sewage into Antarctic waters. In 1980, NSF indicated that such discharges could impact local marine ecosystems. Subsequently, a 1984 report prepared for NSF recommended at least primary treatment in light of substantial concentrations of fecal coliform, ammonia, and hydrogen sulfide detected in the waters off McMurdo base. More recently, a 1988 NSF contractor observed a "significant algal population" on the open water near the McMurdo outfall. However, despite these observations, NSF's new initiative fails to commit to any treatment of wastewater discharges other than installing submerged outfalls and macerators (which were required in 1975) and continued monitoring.

Specifically, NSF's proposal to treat wastewater would not satisfy national standards under the Clean Water Act nor would it likely comply with a newly revised Code of Conduct on Waste Disposal. Indeed, SCAR's panel of experts on waste disposal recommended that sewage from bases with more than 30 people should be treated with rotating biological contactor systems (RBC's). These units reportedly reduce biological oxygen demand and suspended solids to secondary treatment levels. They are currently used at a few coastal stations where they work quite well even at relatively low temperatures. The approximate cost of installation of RBC's is between $500,000 and a million dollars. Like Poland and Brazil, which treat sewage at their research stations, NSF should reduce wastewater discharges to secondary treatment levels initially for McMurdo base and then Palmer station.

Toxic chemicals may also be routinely discharged along with untreated sanitary wastes at NSF's coastal installations. Inasmuch as many of these chemicals appear on EPA's list of "toxic priority pollutants," NSF would be required under the

Clean Water Act to adopt strict effluent limitations. Unfortunately, because wastewater discharges have not been monitored, it is uncertain as to specifically which toxic substances actually enter Antarctic waters. Nevertheless, it is evident that such chemicals pose a significant threat to the environment and also, as the Safety Panel report recognized, possibly to human health. Accordingly, we strongly support NSF's proposal to undertake comprehensive monitoring of the McMurdo and Palmer outfalls. However, if toxic chemicals are detected, NSF must include in its initiative a commitment to eliminate the source of this pollution immediately.

B. SOLID WASTE DISPOSAL

The disposal of solid wastes at U.S. Antarctic research bases over the past three decades also raises serious questions. These wastes have either been discarded in open dumps that are periodically burned, dumped at sea, or buried in a landfill. While NSF has declared that ocean dumping has ceased and its initiative suggests that open burning may be discontinued, it apparently plans to continue operation of a landfill at the Fortress Rock site near McMurdo base. That action flatly violates the 1975 Code and contravenes SCAR's recommendations for revisions to the new Code. It is particularly problematic in light of the Safety Panel's finding that runoff from the fill is polluting Antarctic waters. Rather than explicitly addressing this problem, however, NSF proposes to establish essentially another landfill at the former Winter Quarters Bay dumpsite. There, NSF has slowly removed materials but now it is concerned that hazardous wastes could be re-mobilized. While we appreciate that concern, we cannot endorse these landfills. NSF must clean up these sites after taking the necessary actions to ensure that wastes are not released.

Because solid wastes deposited in Antarctica will remain there for decades if not forever, SCAR recommended that non-combustible wastes and plastics should be removed from the Treaty area. More than half of the research bases in Antarctica remove all non-combustible wastes and at least 15% return combustible wastes as well. Recently, NSF did return more than 1.7 million kilograms of materials to the United States. These efforts, which should be applauded, demonstrate that NSF can afford to remove wastes from Antarctica and that such actions should be undertaken on an annual basis. Yet, rather than committing to this method, the initiative calls for further assessment of solid waste disposal systems to develop information on alternative techniques. Inasmuch as a number of studies have already been undertaken, and both SCAR and the Safety Panel have recommended removal of wastes, it is time for NSF to take substantive actions that address these problems. Accordingly, NSF's new initiative should commit to removal efforts of solid wastes on an annual basis.

C. HAZARDOUS WASTE MANAGEMENT

Antarctic research bases typically also produce "hazardous wastes" that must be removed from Antarctica. Such wastes include spent battery acid, industrial solvents, laboratory and photographic chemicals, contaminated waste fuels, and combustion ash. At least 18 research bases, including those operated by Japan, Italy, and China, remove such wastes on an annual basis. Only recently have U.S. installations also begun to remove particular hazardous wastes from Antarctica. For example, during the 1987-88 season, NSF finally returned hundreds of barrels of waste oil that had awaited shipment out of Antarctica for years. NSF's initiative, which is silent on the question of hazardous waste management, must include a commitment to remove such wastes each year. Like more than 50% of the bases operating in Antarctica, NSF must promptly remove all chemical wastes and combustion ash from the Treaty area.

Moreover, U.S. bases must be prepared to contain and clean up spills of hazardous waste, oil and fuel. The recent oil spills involving the *Bahia Paraiso* and *Humboldt* clearly demonstrate the need for oil spill cleanup equipment on-site at both McMurdo and Palmer stations. We strongly support NSF's proposal to locate this equipment in Antarctica. At the same time, it must be emphasized that those shipwrecks were not the only incidents involving fuel spills in Antarctica this season.

Indeed, in November 1988, almost 24,000 gallons of jet fuel spilled at Williams Field near McMurdo base apparently from an aged rubber storage tank. Unfortunately, immediate cleanup operations could not be undertaken because of insufficient storage capacity for the spilled fuel. We therefore also endorse NSF's proposal to build protective containment structures around storage tanks and suggest that NSF include storage facilities for spilled fuel.

D. ATMOSPHERIC EMISSIONS

In addition, NSF must take actions to reduce pollution of the pristine Antarctic atmosphere. More than 300 tonnes of particulate emissions enter the Antarctic atmosphere each year from generators used to supply power to various Antarctic bases. Ironically, emissions from the generators used at McMurdo base are controlled in the most heavily polluted parts of the United States, but not in Antarctica. This is particularly troubling since emissions from McMurdo station threaten unique terrestrial plants miles away. Italy recognized these problems when it installed emission controls at its Terra Nova Bay station. Yet, NSF's initiative does not follow that example. Inasmuch as the Clean Air Act calls for protection of air quality near "international parks" and national wilderness areas (so-called class I areas), the initiative must include strict controls on emissions from power generators.

The second major source of air pollution in Antarctica -- open burning of combustible wastes -- produces at least 20 tonnes of particulate emissions each year. At U.S. bases, combustible wastes are typically bull-dozed into an open pit and ignited with contaminated waste fuels (an illegal practice under U.S. law) Other nations, including Australia, Brazil and Korea, have been more responsible and reportedly installed controlled incinerators. Both SCAR and the Safety Review Panel recommended that open burning should be quickly eliminated and replaced by incineration with emission controls, and that wastes should be removed from Antarctica. However, NSF's initiative only calls for a design study of an incinerator at McMurdo base and apparently not Palmer Station. Moreover, it again places virtually no emphasis on removing wastes from Antarctica. Clearly, NSF must attach a much higher priority to removing wastes from Antarctica and should immediately cease open pit burning at all U.S. stations in Antarctica.

III. PREVENTING IMPACTS TO ANTARCTIC WILDLIFE AND PROTECTED AREAS

To address the potential impacts of increased human activity in Antarctica on wildlife, the Treaty parties adopted the Agreed Measures for the Conservation of Antarctic Fauna and Flora in 1964. Those measures prohibit any person from taking native Antarctic mammals and birds, and authorize the parties to protect special areas. With passage of the Antarctic Conservation Act in

1978, Congress empowered NSF to enforce these provisions against U.S. nationals. Yet, over the past decade, NSF has failed to fulfill its obligations as a regulatory agency under the Act. Indeed, NSF has consistently construed the Act's provisions in ways that reduce environmental protection and has not effectively enforced regulatory requirements in Antarctica. While the former problem is more one of perspective than money, the latter will ultimately entail increased expenditures for on-site enforcement actions. Recently, NSF did open a position for a "Safety, Environment and Health Officer" presumably to address the latter problem. While we support that action, we suggest that the initiative specify particular actions for that official to pursue.

A. PROTECTION OF ANTARCTIC WILDLIFE

When NSF issued regulations implementing the Antarctic Conservation Act in 1979, it identified 43 bird species and 11 marine mammals for protection. Yet, as many as 77 seabirds and 15 marine mammals actually occur within the Antarctic Treaty area and therefore deserve protection. The Foundation's failure to protect all native Antarctic species results from its very narrow interpretation of the term "indigenous" used in the Agreed Measures. While that term generally means "occurring or living naturally in an area," NSF has taken the position that a species must breed in Antarctica in order to be "indigenous" there. As a result, at least 34 seabird species and 4 marine mammals, which frequently occur in Antarctica, are not afforded protection under U.S. law. The new initiative should call for protection of these species.

Moreover, for those species on the list of protected species under the Act, NSF has failed to implement the principal purpose of the Agreed Measures -- to "minimize harmful interference with the normal living conditions of all native Antarctic mammals or birds." Although Congress very broadly defined the term "take" in the Antarctic Conservation Act to include "harass, molest, and harm," and that term has been construed to include habitat disruption, NSF has typically not scrutinized the effects of dynamite blasting and construction activities on Antarctic wildlife. At the same time, NSF has failed to exercise its regulatory authority over U.S. tour groups that routinely visit sensitive penguin rookeries and seabird nesting areas during the breeding season. To address these problems, NSF's initiative must include funding to support an effective enforcement program in Antarctica.

B. PROTECTION OF SPECIAL AREAS

The Agreed Measures also make it unlawful for any U.S. citizen to enter into any "specially protected area" ("SPA") or "site of special scientific interest" ("SSSI") unless authorized by a permit granted by NSF. To enforce these provisions against U.S. nationals, the Act requires NSF to identify by regulation those SPA's and SSSI's that have been approved by the United States at Antarctic Treaty meetings. Unfortunately, NSF has been rather remiss in formally identifying and protecting these areas. As a result, until late last year, U.S. citizens were free to visit areas that had received international protection but not national status. Clearly, the initiative should not only call for increased protection of Antarctic wildlife but also prompt designation of internationally protected areas.

Finally, for those international areas that have been so designated, NSF has not strictly governed entry into them. For example, U.S. citizens may only enter SPA's if "there is a compelling scientific purpose for such entry which cannot be served elsewhere." Yet, in 1988, the Foundation took an unusually broad interpretation of that exception when it issued permits to media personnel to enter these sites. For SSSI's, NSF has generally failed to exercise its jurisdiction over U.S. citizens outside of the U.S. Antarctic Program. Permits to enter these areas may only be granted for activities "consistent" with management plans prescribed for the site. Yet, U.S. tour groups this year visited at least one SSSI without obtaining NSF permission. Although NSF recently issued regulations that will allow it to enforce these provisions, the initiative fails to call for funding that will allow it to detect actual violations.

IV. ASSESSING AND MONITORING ENVIRONMENTAL IMPACTS

There is no doubt that effective assessment and monitoring efforts will reduce environmental impacts from scientific research and associated activities in Antarctica. Indeed, where potential impacts have not been thoroughly evaluated, these activities have unnecessarily resulted in the loss of Antarctic wildlife. Recently, the Treaty parties adopted guidelines that require each nation to assess impacts before embarking on major projects. Although these guidelines were adopted in 1987, NSF has failed to comply fully over the past decade with similar domestic procedures required under the National Environmental Policy Act (NEPA). Moreover, NSF has still not established an effective system for monitoring impacts and compliance with applicable regulations. Although NSF's initiative does call for increased baseline finding to support environmental assessments and monitoring, it does not specifically commit to addressing the these gaps.

A. ASSESSMENT OF ENVIRONMENTAL IMPACTS

Following the issuance of Executive Order 12114 more than a decade ago, NSF has been required to prepare an environmental impact statement (EIS) for each U.S. activity in Antarctica with potentially significant environmental impacts. To date, NSF has not issued mandatory guidelines governing NEPA compliance nor has it seriously evaluated the potential impacts of its "site-specific" actions in Antarctica. These actions include dynamite blasting and construction activities. Recently, NSF indicated that it plans to update its programmatic EIS. While that effort does not relieve NSF of satisfying the requirements outlined above, it certainly is a welcome step in the right direction. Indeed, it has been almost a decade since the program was last reviewed. Accordingly, increased funding of NSF's annual operating budget should be used to prepare both programmatic and site-specific environmental impact statements for the U.S. Antarctic program.

At the same time, it must be emphasized that NSF has still not implemented many of the "mitigating measures" it promised to undertake in 1980 when it last evaluated the environmental impacts of the U.S. Antarctic Program. These measures include studies of its sanitary waste disposal system to determine whether toxic compounds are present in significant concentrations in untreated raw sewage and if heavy metals are collecting in benthic sediments or organisms. Although NSF did find in 1983 that PCB's and heavy metals occur in substantial concentrations in bottom sediments near McMurdo Base, it still has not determined the source of these toxics or whether they are, in fact, accumulating in the Antarctic food chain. Clearly, the initiative should include a specific request for funds to investigate the causes and scope of this pollution problem.

B. MONITORING ENVIRONMENTAL IMPACTS

Moreover, NSF has not sought to monitor the environmental effects of its activities and to ensure compliance with applicable international authorities and domestic regulations. To date, a number of federal agencies, including the Air Force, Department of Energy, and National Institutes of Health, have established formal "environmental auditing programs." In August 1988, the Environmental Defense Fund developed a detailed "Antarctic Environmental Audit Protocol" that could be used by NSF to evaluate environmental impacts at each U.S. base in Antarctica. While it was too late to conduct this audit for the 1988-89 research season, it is particularly important for next year in light of serious pollution problems and the requirements of Executive Order 12088. Although NSF's environmental initiative calls for a workshop to determine appropriate monitoring actions, we believe that more specific and immediate measures must be pursued including on-site audits at each research base next year.

V. CONCLUSION AND RECOMMENDATIONS

In sum, NSF's environmental initiative is a welcome first step toward addressing environmental impacts from U.S. research activities in Antarctica. However, in the final analysis, it fails to meet its stated objectives -- to clean up past debris and to bring present operations into compliance with current regulations and technology. Indeed, the initiative does not satisfy international and domestic environmental standards and fails to reflect a commitment to pursue more responsible practices that other nations are already following in Antarctica. To correct these problems, NSF should: (1) comply with Executive Order 12088; (2) establish a pollution control program under the Antarctic Conservation Act; (3) commit to secondary treatment of wastewater discharges; (4) eliminate all sources of toxic chemical pollution; (5) cease operation of its landfills in Antarctica; (6) make removal of solid and hazardous wastes, including combustion ash, its highest priority; (7) strictly control emissions from power generators at each base; and (8) immediately cease all open pit burning of solid wastes in Antarctica.

At the same time, the initiative must be expanded to include an effective enforcement scheme to protect Antarctic wildlife and an assessment/monitoring system to reduce all impacts. To achieve the former objective, the initiative should call for increased funding to support (1) protection of all native Antarctic birds and marine mammals and internationally protected areas; (2) careful analysis of all operational activities and development of guidelines defining harmful interference with Antarctic wildlife; and (3) strict regulation of U.S. tour groups that visit Antarctica. To ensure that significant environmental impacts do not occur anywhere in Antarctica, the initiative should include increased baseline funding so that NSF can (1) immediately issue guidelines governing NEPA compliance; (2) prepare environmental assessments for all actions with potential impacts; (3) expeditiously complete a new programmatic EIS; (4) implement the mitigating measures identified in the 1980 EIS, including a study of PCB contamination; and (5) create an independent environmental auditing program.

Thank you again for the opportunity to testify on this important subject. I would be pleased to respond to any questions that the Subcommittee might have about my testimony.

THE CHRISTIAN SCIENCE MONITOR

Tuesday, February 28, 1989

SCIENCE COMMENTARY

Keeping Antarctica Clean

ROBERT C. COWEN

ARGENTINA's recent diesel fuel spill is an environmental shock for Antarctica. But the pollution, trash dumps, and occasional deliberate destruction of wildlife habitat associated with the Antarctic research stations have been a long-playing tragedy.

This could worsen when mining begins in the next century, unless the cleanup efforts some nations have started are intensified, emulated by others, and reinforced by stricter environmental control throughout the frozen continent. A scientific committee of the Antarctic Treaty nations is to consider better waste disposal methods this October. Such methods are urgently needed.

The National Science Foundation, which administers the United States Antarctic program, has often expressed concern to protect the Antarctic environment. Yet it admits its hands are not entirely clean.

The United States runs four of the 57 Antarctic research stations maintained by 18 nations. Last August, the Environmental Defense Fund in Washington focused attention on the pollution of those US stations. It includes open trash burning, trash dumping in pits rather than removal to the United States, trash dumping at sea, and discharge of raw sewage directly into the ocean at McMurdo Station. A recent report by the Australian Greenpeace organization has repeated these complaints.

For its part, the National Science Foundation explains that it has long been aware of the trouble and has been trying to clean up the pollution. Its critics recognize the foundation's good intentions. But at the same time they complain that remedial efforts have been too slow and have yet to correct abuses that, in some instances, may violate Antarctic Treaty provisions.

France, by its own admission, has most flagrantly violated the treaty. It has callously blown up penguin rookeries and sea bird breeding grounds in building a new airport.

John Talmadge of the National Science Foundation Polar Programs Division has outlined the basic challenge. He notes that, when the research stations were first established, inhabitants were more concerned with sheer survival in a harsh environment than with anything else. This created a mind-set that has to be changed. New environmental standards are needed.

If the United States is to provide leadership in setting those standards, it has to clean up its own act. The foundation is asking for the money to do what it has talked about for a decade. Its 1990 budget request includes initial funding for a four-year $30 million Antarctic environmental program. That would include proper waste-water treatment. It would involve cleaning up trash dumps and other environmental blights. It would bring trash home as Australia and New Zealand already do.

Congress should examine this program carefully to make sure it is adequate. Then it should give the foundation the funds to do the job right.

Antarctica is the last large pristine environment on our planet. Nations working there owe it to themselves and to the rest of the world to protect that environment. The committee on waste disposal standards that meets in October has an urgent task. And the United States should be ready to lead in that work by example as well as by precept.

A Tuesday column

Comment
The Arizona Daily Star
Founded 1877
Michael E. Pulitzer, Editor & Publisher Susan J. Albright, Editorial Page Editor

EDITORIALS

Scientific assault

Congress should force Antarctic cleanup

The scientific assault on Antarctica has fouled the most pristine environment on Earth — and Americans are heavily to blame. As it did 10 years ago, Congress must put pressure on the foot-dragging National Science Foundation.

The foundation's disposal activities violate both U.S. and international disposal laws, according to a report by the Environmental Defense Fund. Violations include open-pit burning of wastes, ocean-dumping of sewage and dynamite blasting near wildlife colonies.

McMurdo Sound, which is next to the American station, is more polluted than any U.S. waterway. The foundation told a Senate panel last year that it was "in full compliance" with the international Code of Conduct on Waste Disposal. But it has maintained a landfill at the station since the early '80s, in clear violation of that code.

In 1978, Congress directed the agency to create a pollution-control program. Two years later, the foundation promised to study the environmental impact of its sanitary-waste disposal, and to issue pollution-control regulations. It has done neither.

"Nobody here wants to rape Antarctica," protested a foundation spokesman. "We want to preserve it." Yet the tissues of penguins and seals now yield levels of toxic PCB and heavy metals. Scientists cannot ignore the undeniable signs of damage to Antarctica's pristine environment and wildlife.

If the National Science Foundation wants to make good on its preservation promises, it should follow the recommendations of the Environmental Defense Fund's report. Those include removing wastes from the continent, controlling incinerator emissions and treating sewage.

The United States did not pollute Antarctica alone; 17 other nations also have bases there. Nonetheless, American scientists must begin to clean up their considerable share of the pollution.

Several nations have better disposal methods than the United States: Poland and New Zealand treat sewage and control incinerator emissions. Australia incinerates wastes. Japan removes chemical wastes from the continent.

The United States should do at least as well. Before Congress reallocates the foundation's budget, it must demand that the agency clean up its act.

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AUG 22 1988

EDITORIALS

So much for purity

Pollution at the South Pole

The image most people have of those involved in scientific research is that they are careful and systematic, striving always towards purity and perfection. The white lab coats that researchers like to wear don't hurt that image.

Of course, most people don't have a chance to visit any of the four National Science Foundation bases in Antarctica, where scientists and researchers toil away to unlock the secrets of nature in one of the globe's last nearly pristine environments. There, apparently, a researcher's white lab coat might be sullied.

The Environmental Defense Fund has charged that the NSF is a major polluter in the Antarctic, dumping untreated sewage and garbage into its waters, openly burning other waste materials, and failing to control the emissions of diesel power generators.

In fact, the EDF charges the federal agency with committing environmental sins it couldn't get away with in the United States because of various anti-pollution laws. It also said that the McMurdo Sound waterway adjacent to the largest NSF installation is more polluted than any U.S. waterway and that highly toxic polychlorinated bi-phenyls and heavy metals are being found in the tissues of penguins and seals.

So much for purity in scientific research. "It is incredible that these practices are observed by the U.S. government in the most pristine environment in the world," said Bruce Manheim, an attorney and scientist who authored a report for the EDF on the problems. "Rather than addressing environmental threats in Antarctica, NSF has ignored them."

The NSF has begun to notice some of the pollution it created. It has recently shipped scrap metal and drums of waste oil out of the Antarctic to be properly disposed of. Jack Talmadge, head of the agency's polar coordination and information section, said raw sewage is dumped into Antarctic waters because chemicals to treat it would be more harmful than the sewage itself.

Talmadge said many of the EDF's charges are true, and that the agency is taking other steps to clean up its act. And apparently the agency is not the only polluter in the Antarctic. Some of the other nations doing research there also contribute to the problem, the EDF says.

However, Japan and Australia remove all wastes from their bases, and Poland and New Zealand treat sewage and control incinerator emissions.

The NSF, the environmental group says, should begin to comply with the international Code of Conduct on Waste Disposal adopted in 1975. The EDF says the foundation's landfill at its McMurdo bases does not comply with that code, even though last year the agency assured a U.S. Senate panel that it was in compliance.

Congress should now mandate that compliance and make sure NSF follows through. It should also force the agency to clean up its act.

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AUG 20 1988

Dirtying the most pristine place

Antarctica remains the most pristine place on Earth, but it might not stay that way. Year after year, visitors abuse the environment and pollute the continent's polar expanses.

According to a report released this week by an environmentalist group, the Environmental Defense Fund, one of the chief polluters is a government agency. The report says U.S. research bases dirty Antarctica's environment in violation of U.S. laws and international agreements.

It seems the National Science Foundation, which supervises U.S. scientific research in Antarctica, has for decades permitted ocean dumping of untreated sewage and toxic chemicals, burning of solid wastes in open pits and the use of diesel generators with no emission controls.

The results are apparent. McMurdo Sound, adjacent to the largest U.S. installation, is reportedly more polluted than virtually any waterway in the United States. Scrap metal piles up in landfills. Wildlife is threatened. Toxic heavy metals have been found in penguins' tissue.

Not only is the polluting bad in itself; it sets an ominous precedent. At a time when oil, gas and mineral prospectors are preparing to descend on Antarctica, the United States has failed to show it recognizes basic obligations to clean up after itself. If government-funded scientists can't follow the rules, how can developers be expected to?

The government says it is moving to improve environmental controls in Antarctica. But previously promised improvements have been slow in coming. As long ago as 1960, for example, the U.S Navy pledged to build a water-treatment plant and an incinerator with emission controls. Neither has been built.

The NSF also notes that its outposts aren't the only polluters. But the foundation's practices hardly put it in a position to press for better pollution control by less-responsible nations with Antarctica bases.

The U.S. government allows American exporters to sell, to Third World nations, pesticides that are banned in the United States. It allows firms to build plants overseas that wouldn't meet American safety standards. It allows companies to ship garbage to nations that don't share Americans' concern for proper disposal methods.

So perhaps it's not surprising that a U.S. agency has been polluting Antarctica without regard for what U.S. laws allow. This doesn't make the NSF's disdain for a wondrous continent any less outrageous.

Mr. Walgren. How is this on the waste disposal issue, which I gather you focus on, Mr. Craig? There is a treaty code of conduct. Does that cover waste disposal? Is that right?

Mr. Craig. There is a general framework that is recommended within the treaty nations; in fact, I think Mr. Manheim is better qualified to comment on that.

My function on the Safety Panel was largely in the area of looking at our—we did not really get into those issues, and I do not consider myself that conversant, but I think basically——

Mr. Walgren. Well, let me address that to Mr. Manheim, then. Could you outline the way the—there is a code of conduct on waste disposal. Has the NSF addressed that specifically? How have they failed? Where have they failed to address that code?

Mr. Manheim. Yes, I would be happy to address that, Mr. Chairman.

In 1975 the Antarctic Treaty parties adopted what is now known as the Code of Conduct on Waste Disposal. It established a number of recommendations for research bases operating in the Antarctic to observe to reduce their waste disposal problems.

Our research suggests that the National Science Foundation has failed to observe those recommendations in at least three ways. First, it still continues to operate this landfill that I referred to earlier in my remarks, despite this 1975 code banning such operations.

Secondly, the 1975 code has required bases in the Antarctic to macerate human wastes before they are discharged. NSF is now, 13 years later, finally going to do that.

And, finally, the code also bans the disposal of plastics in Antarctica, yet those plastics have been observed in the landfills at McMurdo base.

I might note that that 1975 code is so flexible that many Antarctic Treaty nations are now considering very serious and much stronger revisions to it. In fact, this Scientific Committee on Antarctic Research recently convened a panel of experts on waste disposal, and they have recently issued a draft report that suggests a number of much stronger changes to this 1975 code. Our concern is that the NSF initiative not only will necessarily meet the 1975 code but the new revisions that are adopted to this much stronger code that may be in place as early as October of this year.

Mr. Walgren. Perhaps you could outline, with a little submission, what seem to be the major proposals by the new group, or the new proposals being made, and how the NSF initiative sort of conforms to that, or where it is not responsive.

Mr. Manheim. I would be happy to do that, Mr. Chairman, although my testimony does to some extent go into specifically that question. But just briefly here, I can mention that open-pit burning has essentially been recommended to be phased out by this special panel, yet NSF only calls for the design of an incinerator at McMurdo base, not Palmer station or South Pole.

In fact, perhaps the most important recommendation of the SCAR panel that I suspect will be adopted later this year in October is that the countries operating in the Antarctic, at a minimum, observe national environmental standards for protection of the environment. In our testimony, we have essentially evaluated NSF's initiative in that context. Does it meet standards established under the Clean Air Act, the Clean Water Act, our hazardous waste laws? And, unfortunately, the answer is no. But I would be happy to include an additional submission, if you like.

Mr. **Walgren**. All right. Well, I would invite you to do that in some short, focused form.

[Material to be supplied follows:]

ENVIRONMENTAL DEFENSE FUND

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March 29, 1989

The Honorable Doug Walgren
Chairman, Subcommittee on Science,
Research and Technology
Rayburn House Office Building
Suite 2321
Washington, D.C. 20515

Dear Congressman Walgren:

This letter responds to your request for a specific description of the extent to which the recent environmental initiative of the National Science Foundation (NSF) would implement recommendations of the Scientific Committee on Antarctic Research (SCAR) for improved environmental practices in Antarctica. Those recommendations (appended to this letter) are contained in a report by SCAR's panel of experts on waste disposal, and were based on a survey of existing waste disposal practices in Antarctica. Although that report is still undergoing minor grammatical changes, its recommendations will form the basis for revisions to the 1975 "Code of Conduct on Waste Disposal" by the Antarctic Treaty parties in October 1989. As the description below makes clear, NSF's initiative conforms to certain SCAR measures but falls short of fully implementing SCAR's most important recommendations.

Waste Management Planning

SCAR's first major proposal calls for waste management planning to reduce the amount of waste produced or discarded in Antarctica. To that end, parties must develop annual plans for waste management (Rec. 2), create a waste disposal classification scheme (Rec. 3), annually exchange information (Rec. 5), nominate a "waste management official" (Rec. 6), and meet periodically to consider waste disposal problems (Rec. 7). NSF's plans to assess its current solid waste system and to develop a new approach, and its intention to hire a Safety, Environment and Health Officer, apparently respond to these recommendations.

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Unfortunately, NSF's initiative does not explicitly commit to implementing SCAR's most significant recommendation governing waste management planning -- Recommendation 4. That recommendation urges Antarctic operators to take into account national environmental standards when developing waste management plans and to apply those standards where they are higher than those contained in the new Code of Conduct. It is clear that U.S. environmental standards established under various federal environmental laws will almost certainly exceed whatever revisions are made to the Code later this year. NSF's General Counsel's Office is currently studying these environmental laws and will issue an opinion on their applicability to U.S. activities in Antarctica later this spring.

Removing Wastes from Antarctica

Another set of SCAR's recommendations concerns removal of wastes from Antarctica. Generally, research stations must remove excess fuel and fuel drums (Rec. 9); abandoned fuel drums (Rec. 10); cultures of micro-organisms and introduced avian products (Rec. 15); combustible wastes, including polyvinyl chloride and polystyrene foam, which are not effectively incinerated (Rec. 16); plastic wastes of unknown composition (Rec. 17); non-combustible solid wastes and liquid wastes other than sewage discharges (Rec. 19); and radioactive materials, batteries, and wastes containing heavy metals or harmful compounds (Rec. 24). Although NSF removed many of these types of wastes from U.S. bases last year, the initiative calls for further assessment and does not commit to removing such wastes from Antarctica on an annual basis.

Eliminating Open Pit Burning

The SCAR recommendations also seek to eliminate open pit burning throughout Antarctica. All combustible wastes not removed from the continent must be burned in incinerators that reduce harmful emissions to the maximum extent practicable (Rec. 16). Where it is "necessary" to burn wastes in open pits, operators must limit particulate deposition on land and avoid deposition over sensitive areas (Rec. 18). In response to these measures, NSF's initiative calls for a study of an incinerator at McMurdo base and suggests that Palmer Station's much smaller size raises the question of need for an incinerator there. The initiative, therefore, again calls for further studies and does not necessarily reflect a commitment to eliminate open pit burning at all U.S. bases. Moreover, in the event that open burning occurs during these studies, the initiative does not call for immediate monitoring or deposition controls.

Controlling Wastewater Discharges

The SCAR report also evaluated the problem of untreated human and liquid wastes being discharged at sea. Specifically, Recommendation 22 calls for at least primary treatment, such as maceration, of large quantities of these wastes (i.e., from more than 30 people) before disposal at sea. At the same time, SCAR indicated that it would be "advantageous" to treat very large quantities through Rotating Biological Contactor Systems, or their equivalent, to reduce further biological oxygen demand and suspended solids. NSF's initiative includes plans for macerators (required by the 1975 Code) and submerged outfalls at both Palmer and McMurdo bases. However, other than calling for continued monitoring and assessment, the initiative does not necessarily follow through on SCAR's recommendation that discharges from McMurdo base with its 1300 summertime residents receive secondary treatment.

Ceasing Operation of Landfills

Another problematic issue considered by SCAR concerns the burial of wastes at coastal stations in Antarctica. Although the 1975 Code of Conduct flatly banned such operations, NSF has maintained a landfill at the Fortress Rock site near McMurdo base since the early 1980's. Uncontrolled runoff from that landfill is reportedly polluting Antarctic waters. The SCAR report highlighted the long term impacts of such leaching on soils and benthic organisms, and did not propose to remove the 1975 prohibition. Indeed, it further recommended against the disposal of all chemical wastes to land (Rec. 25). Nevertheless, NSF's initiative apparently contemplates continued operation of the Fortress Rock operation.

Moreover, NSF proposes to establish essentially another landfill at the former Winter Quarters Bay dumpsite near McMurdo base. NSF has indicated that, prior to the late 1970's, wastes generated at that base were dumped and burned at this dumpsite. Hazardous wastes may be buried at this site and could be leaching into Antarctic waters. Although NSF has slowly removed these wastes over the recent past, it now proposes to cover the area with fill material and conduct periodic monitoring. That proposal contravenes the 1975 ban on landfills and SCAR's recommendation that, "where practicable," waste disposal sites should be cleaned up (Rec. 14). Hence, NSF should determine whether it is possible to remove such wastes before deciding to cover this area with fill.

Other Miscellaneous Matters

Finally, there are several miscellaneous SCAR recommendations that NSF's initiative would implement and others where it fails to follow through. For example, the initiative would address SCAR's recommendations limiting the importation of plastics into Antarctica (Rec. 8), assessing wastewater pits at certain inland sites (Rec. 11), informing all expedition staff of required environmental practices (Rec. 13), cleaning up certain abandoned work sites such as Cape Hallett station (Rec. 14), and establishing storage facilities to prevent dispersal of wastes by wind or scavengers (Rec. 20). On the other hand, NSF's initiative does not fully implement SCAR's recommendations calling for removal of all wastes from inland stations (Rec. 26) and field camps (Rec. 27), or development of storage and incineration facilities on board ships operating in Antarctic waters (Recs. 12 and 28).

In sum, NSF's initiative does not fully implement the most significant SCAR recommendations concerning removal of wastes from Antarctica, open pit burning, discharges of untreated liquid wastes, and continued operation of landfills. Instead, it generally calls for further studies to assess the situation. Moreover, NSF's initiative does not reflect SCAR's concern that U.S. environmental practices in Antarctica at least achieve the same level of protection required in the United States. It remains to be seen whether NSF's forthcoming legal opinion on this issue will alter that position. As EDF indicated in its recent report evaluating NSF's actions in Antarctica, U.S. activities in Antarctica should conform not only to international requirements but also to sound U.S. environmental policy.

Thank you for your attention to this issue.

Sincerely,

Bruce S. Manheim, Jr.
Attorney and Scientist
Wildlife Program

Attachment

6.2 Proposed code of conduct for Antarctic expeditions and station activities

The following clauses, describing objectives and practices which are logistically feasible, are recommended:

Waste management planning

1 It is recommended that, to the maximum extent possible, National Antarctic Operators should endeavour to reduce the amount of waste produced, or disposed of, in Antarctica, so as to minimise the impact of waste on the Antarctic environment and to minimise interference with scientific research.

2 National Antarctic Operators should prepare, and annually update:

(i) plans for waste management (including waste reduction, storage, and disposal), showing for each fixed site, for field camps generally, and for each vessel (other than small boats, which for this purpose should be regarded as part of the operations of fixed sites or of vessels):

- programs for clean up of existing waste disposal sites and abandoned work sites
- current and intended waste management arrangements;
- current and intended arrangements for the analysis of the environmental effects of Antarctic waste and waste management systems; and
- efforts to minimize any environmental effects of waste and waste management.

(ii) An inventory of locations of past activities (such as traverses, fuel depots, field bases, crashed aircraft), as far as is practicable, before the information is lost, so that they can be taken into account in planning future scientific programs (e.g. snow chemistry, pollutants in lichens, ice core drilling etc.).

3 National Antarctic Operators should establish a waste disposal classification as a basis for recording wastes and to facilitate studies aimed at evaluating the environmental impacts of operational and scientific activity. Wastes produced may be classified as sewage and domestic liquid wastes (Group 1); other liquid wastes and chemicals, including fuels and lubricants (Group 2); solids to be combusted (Group 3); other solid wastes (Group 4); and radioactive materials (Group 5). Source classification codes, which represent individual processes or functions logically associated with points of waste creation, may be used in auditing studies.

4 In the development of their waste management plans, National Antarctic Operators should, where appropriate, take into account their respective national environmental standards. Where national environmental standards are higher than those recommended in this Code of Conduct, those national standards should apply.

5 National Antarctic Operators' waste management plans should be included in annual exchanges of information in accord with the Antarctic Treaty and recommendations of the Consultative Parties. The formats used for these plans can , initially, be at the discretion of each National Operator.

6 National Antarctic Operators should nominate a person within their organisation, as a waste management official, who would develop and monitor waste management plans. Implementation in the field should be delegated to an appropriate person at each site.

7 The Managers of National Antarctic Programs should meet together from time to time to consider problems, prospects, and opportunities for cooperation in Antarctic waste management and to advise their governments on appropriate steps, in this area, which may be taken by the Antarctic Treaty Consultative Parties.

8 National Antarctic Operators should not send to the Antarctic, pesticides, polychlorinated biphenyls (PCB's), non-sterile soil or polystyrene beads, chips or similar forms of packaging. Additionally, they should discourage the use of polyvinyl chloride (PVC) products in packaging and should advise their expeditions of PVC products being provided.

9 The removal of fuel drums, both full and empty, should be seen as a legitimate cost on projects and when a program is completed, or for some other reason the fuel dump is no longer necessary, all remaining fuel and drums should be removed.

10 National Antarctic Operators should establish a long term program to remove already abandoned fuel drums, where such removal is practicable; where the transport equipment which delivered the drums is no longer available in the same area, the drum sites should be recorded for clean up at the first opportunity.

11 When planning the location of inland stations where it is intended to concentrate waste in deep ice pits, sites on ice flow lines which terminate at ice free areas or areas of high ablation should be avoided where possible.

12 National Antarctic Operators should incorporate on-board waste compaction, storage and incineration facilities in the design and construction of ships.

13 National Antarctic Operators should arrange for all expedition staff to receive training designed to limit the impact of their operations on the Antarctic environment and to inform them of required practices.

Waste disposal measures

14 Where practicable, National Antarctic Operators should clean-up their waste disposal sites and their abandoned work sites.

15 The following should be removed or else incinerated, autoclaved or otherwise treated to make sterile:

- residues of introduced animal carcasses;
- cultures of micro-organisms; and
- introduced avian products.

16 All combustible waste, which is not removed from the Antarctic, should be burnt in incinerators designed to reduce harmful emissions to the maximum extent practicable. PVC, polyurethane foam, polystyrene foam or lubricating oils which contain additives which are widely recognised as products which would produce harmful emissions, should not be burnt unless equipment is installed which neutralises the harmful emissions produced. While burning of wastes is carried out in basic incinerators, no plastics should be burnt and operators should limit particulate emissions as much as practicable.

17 All plastic wastes of unknown composition should be removed from the Antarctic Treaty Area, unless incinerated in circumstances where equipment is installed which neutralises the harmful emissions which may be produced.

18 National Antarctic Operators should work toward eliminating open burning and should not burn any plastics or rubber other than in incinerators designed to reduce harmful emissions to the maximum extent practicable. If it is necessary to dispose of waste by open burning, operators should take care with the wind, and the type of waste to be burnt, to limit, as far as practicable, particulate deposition on land and to avoid deposition over sensitive areas.

19 Wherever practicable, solid, noncombustible waste should be removed from the Antarctic Treaty Area; if it cannot be transported to land sites outside the Antarctic, it should not be disposed of in inshore locations but in deep water at selected dumping sites, or outside the Antarctic Treaty Area, and in accordance with appropriate international agreements.

20 Waste to be burnt, or removed, should be stored in such a way as to prevent it being dispersed by wind or scavengers.

21 Any waste dumping at sea should be carried out in accordance with the International Convention for the Prevention of Marine Pollution by the Dumping of Wastes and Other Matter, otherwise known as the London Dumping Convention (LDC).

22 Sewage and, where practicable, domestic liquid wastes, should not be disposed of onto ice-free land but may be disposed of direct to the ocean, preferably where conditions exist for rapid dispersal, with large quantities (from, say, over 30 people) first receiving at least primary treatment, such as maceration. It may be advantageous to treat very large quantities through Rotating Biological Contactor Systems, or equivalent, to reduce BOD and suspended solids.

23 Other liquid wastes, solid non-combustible waste, PVC, polyurethane foam and polystyrene foam should, generally, be removed from the Antarctic Treaty Area.

24 Radio-active materials, batteries and wastes containing high levels of heavy metals or harmful, persistent compounds should be removed from the Antarctic Treaty Area.

25 Disposal of chemical waste to land should not occur.

26 At inland stations, National Antarctic Operators should make every possible effort to remove waste from the area; where this is not practicable, it must be concentrated in ice pits.

27 Wherever practicable, wastes generated at field camps should be removed to their supporting stations, bases or ships for proper disposal or subsequent removal from the Antarctic Treaty Area.

28 Where ships are not fitted with incinerator facilities, Antarctic ship operators should, whenever practicable, stockpile wastes, excluding untreated sewage and domestic effluents, for appropriate disposal at stations, bases, or in deep water at selected sites or

outside the Antarctic Treaty Area. The incineration of ship-board wastes should be conducted at sea, preferably outside the Antarctic Treaty Area, unless the incinerators are of the type which are designed to reduce harmful emissions to the maximum extent practicable.

29 Nothing in the preceding clauses should take precedence over safety.

30 The preceding clauses should be followed by any non government operator in the Antarctic.

Mr. WALGREN. I do not have a great background in this area, and I wanted to ask Mr. Craig, you are focused predominantly on safety concerns, is that correct?

Mr. CRAIG. Yes, Mr. Chairman, but as I said in my remarks, safety and the environment become in certain respects interchangeable down there, and I think that good environmental procedures are fundamental to safe management and safe operation. So the lines blur and they overcross, and I think that what is interesting is that a good environmental policy in Antarctica, I think, will also make for much safer operation on the part of U.S. personnel.

Mr. WALGREN. What is it that got us focused on safety in our operations down there? I can understand the environmental side, but the safety side is something that is striking to see about $10 million and then $30 million being directed toward a project which includes, as a large part, safe operations.

Mr. CRAIG. Well, I think the safety aspect of the operations in Antarctica was dramatized by an incident which occurred approximately 3 years ago in which two civilian workers strayed off the marked path near the New Zealand base at the Scott base, which is on the other side of the peninsula on which McMurdo base is also situated, and they wandered from the path and dropped down through some crevasses—that is, walking down—and first one fell in and the other fell in, and they were both subsequently taken from the crevasse by a rescue group of New Zealanders and Americans, but they both died from exposure and their injuries.

That dramatized the need, at least in the eyes, I think, of the leadership in the NSF, and I think also with regard to the operator down there, ITT, that something had to be done to ensure better safety procedures. I think this was in some ways not the most dramatic safety need that we are going to see over the years in operating in Antarctica that civilian workers are going to, in their free time, wander off and fall in crevasses.

I think there are many more worrisome things, and also things which will be occasioned by the impact of tourism down there, with people now doing cross-country ski trips to the South Pole, flying into the Vincent Masif to climb in that area, and things of that sort. The potential for accidents, for real accidents of some magnitude, and the employment of American resources to rescue is going to be a much bigger problem in the long run.

But, in any case, that was one of the things that triggered it. I think there have been a total of something like 46 fatalities in Antarctica over a period of some 40 years of operation down there, and I think that, actually, in terms of numbers of lives lost, there has not been as high an attrition rate as one might expect given the real danger that goes with that environment.

And that in turn, I should add, Mr. Chairman, brought us to look at environmental issues and health issues as part of the same ball of wax, that safety, environment, and health were seen to be somewhat inseparable.

Mr. WALGREN. And, among others, your recommendation is that someone be in charge?

Mr. CRAIG. Yes. I made specific comment on the office of Safety Environment and Health Officer. We strongly recommended that in the panel's report, and I believe that the agency is now looking for such an officer. I just urge that that person be found at the earliest possible moment. I think that person also would begin to make effective some of the recommendations my colleague, Mr. Manheim, and I are both making as to implementation and getting on with this whole environmental operation.

Mr. **Walgren**. Mrs. Morella?

Mrs. **Morella**. Gentlemen, do you think that there is a need for more legislation to help to clean up in that movement in the Antarctic?

Mr. **Manheim**. It is a good question. I think, to some extent, much of the legislation is already there. The Antarctic Conservation Act was adopted in 1978 and does give NSF plenary authority to address many of these problems.

However, the problem has been that the agency has been reluctant to, in fact, aggressively enforce these provisions. For example, in 1978 Congress directed NSF to identify pollutants and to identify measures for the control of the discharge of those pollutants. Yet, 10 years later, that has not been done. Moreover, NSF has authority to issue permits to U.S. citizens who take or harass wildlife or even, for that matter, enter specially protected areas; yet the agency has not aggressively enforced those provisions, either.

In fairness, it is quite difficult because you have tour groups operating down there as well as just simply private expeditions who are difficult to follow. You have to actually be at these areas, observe them, to enforce these provisions.

But, nonetheless, my view is that maybe less discretion and more of a mandate from a Congress in this issue would be very helpful.

Mr. **Craig**. Congressman Schneider——

Mrs. **Morella**. Does it say Schneider? She is in the next room. I am Morella.

Mr. **Craig**. I am sorry; I beg your pardon. I did not think I recognized—I met your colleague earlier, and I was thinking my mind was going, which it probably is.

But I would like to comment that I think that the regulatory framework is adequate. I think that I should comment that my impression in Antarctica—and it has been my impression wherever we operate in remote areas, in the Arctic or in Antarctica or places like that, or even, for that matter, in military operations overseas, which I experienced during World War II—different things happen, and I think that one of the problems with operating in Antarctica is the need and the feeling within the administrative group managing and operating in Antarctica to put as much money into the science operation as possible.

I could not help reflecting, as the astronomers were commenting on their shortage of funds and their sense of neglect, and so on, the Antarctic operation really has been driven toward getting more research, trying to get more people in the field, trying to fulfill those obligations, and I think, in a sense, it has caused a certain amount of neglect, But I think, also, there has not been the mandate, a strong enough mandate, and that would be, I think, more important, that Congress says you will and you need to, and we will try to help you get it done.

But the resources have been rather limited for the importance of what Antarctica is all about, and we really have not talked about the presence issue. So I think that given the need for proper environmental management and the presence issue and the conduct of science, the whole thing makes it a very compelling kind of overall mission, and you cannot neglect the environment in the process.

Mrs. **Morella**. Thank you. I think what you are saying, both of you, is that despite the obstacles—the monetary ones, the terrain itself, the tour operations—it would help significantly if we more specifically spelled out a mandate.

Mr. **Manheim**. I think that is certainly my view, yes. Over the past decade or so, despite the presence of a number of requirements, they have simply not been observed, and I do think that additional congressional oversight in this respect would be very helpful.

Mrs. **Morella**. Thank you.

Thanks, Mr. Chairman.

Mr. **Walgren**. Thank you, Mrs. Morella.

Let me, on behalf of all of us, thank you for participating in our process, and we appreciate your being a resource to the committee.

Thank you very much.

Mr. **Manheim**. Thank you.

Mr. **Walgren**. That concludes today's hearing, and we are on for Thursday next at 9:30 in the morning with more on the National Science Foundation, including the director and other officials thereof.

Thank you very much. The subcommittee stands in recess.

[Whereupon, at 12:02 p.m., the subcommittee recessed, to reconvene at 9:30 a.m., Thursday, March 16, 1989.]

OVERSIGHT OF THE NATIONAL SCIENCE FOUNDATION

THURSDAY, MARCH 16, 1989

House of Representatives,
Committee on Science, Space, and Technology,
Subcommittee on Science, Research and Technology,
Washington, DC.

The subcommittee met, pursuant to recess, at 9:40 a.m., in room 2318, Rayburn House Office Building, Hon. Doug Walgren (chairman of the subcommittee) presiding.

Mr. Walgren. Let me welcome you all to our hearing this morning on the National Science Foundation. This is the third hearing of our subcommittee in oversight of the National Science Foundation.

We are happy to have with us this morning Erich Bloch, the Foundation's director, accompanied by Dr. James Powell, who represents the National Science Board, to talk about plans and priorities in the proposed fiscal year 1990 budget and to talk about other aspects of the Foundation's emphases and focuses.

In a hearing on March 9 we had the opportunity for non-government witnesses to comment on NSF's programs, particularly in science education and pre-college science and math, and on March 14 we had a hearing in which we heard a number of individuals focused on the behavioral and the social sciences, as well as astronomy and the Antarctic program that the NSF carries out.

The NSF Authorization Act of 1988 authorizes appropriations for five years, a first step for us in multi-year authorizations, and provides for doubling the Science Foundation's budget over a five-year budget. We all certainly welcomed the allocation and the emphasis that President Bush gave and his prominent support for achieving this goal in the Joint Session of Congress address last month.

The research and education programs of the National Science Foundation represent to all of us, I think it is fair to say, an investment in the Nation's future that we would be really penny wise and pound foolish not to make.

This morning we are pleased to have the opportunity to hear how the NSF plans to allocate proposed budget increases in fiscal year 1990. Even with the anticipated budget growth, it is clear that there are many more opportunities that exist in research and education than we can actually fund, and that certainly raises directly the question about the process that NSF uses in establishing its priorities within its operations, especially the difficult problem of applying priorities across different fields of science. And how do you decide how much should go in one area and how much in another when the areas are really quite different. We look forward to talking to Director Bloch and Dr. Powell about that this morning, among other things.

Science and engineering education continues to be, I think, perhaps the greatest focus of concern to this subcommittee. We note the proposed increase of 63 percent or thereabouts in one view of the undergraduate programs, when you take all the programs across the Foundation. But it is also true that the focused programs within the Science and Engineering Education Directorate reflect very little change whatsoever from year to year for undergraduate programs.

At the same time, we know that pre-college programs are of dominant importance, and they are more directly funded through the SEE. And yet their actual growth is less than the percentage growth of other aspects of the Foundation, and certainly we all emphasize the priority that they should have. We would like to raise that when we get to testimony and discussion.

Let me recognize other Members for opening statements, and then I want to recognize our colleague from Michigan, Howard Wolpe, for particular introductions. But I will turn now to the Ranking Minority Member of the committee for opening comments he would like to make.

[The prepared opening statement of Mr. Walgren follows:]

OPENING STATEMENT OF THE HONORABLE DOUG WALGREN (D-PA) ON NATIONAL SCIENCE FOUNDATION OVERSIGHT HEARING

March 16, 1989

THIS IS THE THIRD HEARING ON OVERSIGHT OF THE NATIONAL SCIENCE FOUNDATION. WE ARE PLEASED TO HAVE WITH US THIS MORNING MR. ERICH BLOCH, THE FOUNDATION'S DIRECTOR, AND DR. JAMES POWELL, REPRESENTING THE NATIONAL SCIENCE BOARD, TO PRESENT PLANS AND PRIORITIES IN THE PROPOSED FISCAL YEAR 1990 BUDGET AND TO DISCUSS VARIOUS ASPECTS OF THE FOUNDATION'S CURRENT ACTIVITIES. A HEARING ON MARCH 9 PROVIDED AN OPPORTUNITY FOR NON-GOVERNMENT WITNESSES TO COMMENT ON NSF'S PROGRAMS FOR PRECOLLEGE SCIENCE AND MATHEMATICS EDUCATION, AND A HEARING ON MARCH 14 OBTAINED TESTIMONY ON NSF RESEARCH PROGRAMS IN THE BEHAVIORAL AND SOCIAL SCIENCES AND IN ASTRONOMY, AS WELL AS NSF ACTIVITIES IN SUPPORT OF THE U.S. ANTARCTIC PROGRAM.

THE NSF AUTHORIZATION ACT OF 1988, WHICH AUTHORIZES APPROPRIATIONS THROUGH FISCAL YEAR 1993, PROVIDES FOR DOUBLING THE NSF BUDGET OVER THE 5-YEAR PERIOD. WE WERE PLEASED THAT PRESIDENT BUSH PROMINENTLY SUPPORTED ACHIEVING THIS GOAL IN HIS ADDRESS TO A JOINT SESSION OF CONGRESS LAST MONTH. THE RESEARCH AND EDUCATION PROGRAMS OF NSF REPRESENT AN INVESTMENT IN OUR NATION'S FUTURE WHICH WE CANNOT AFFORD NOT TO MAKE.

THIS MORNING WE ARE PLEASED TO HAVE THE OPPORTUNITY TO HEAR

HOW NSF PLANS TO ALLOCATE PROPOSED BUDGET INCREASES IN FISCAL YEAR 1990. EVEN WITH ANTICIPATED BUDGET GROWTH, WE ARE, OF COURSE, AWARE THAT MANY MORE OPPORTUNITIES EXIST IN RESEARCH AND EDUCATION THAN CAN BE SUPPORTED. WE ARE THEREFORE PARTICULARLY INTERESTED IN LEARNING MORE ABOUT THE PROCESS USED AT NSF TO ESTABLISH FUNDING PRIORITIES, ESPECIALLY PRIORITIES ACROSS DIFFERENT FIELDS OF SCIENCE. WE HOPE DIRECTOR BLOCH AND DR. POWELL WILL ADDRESS THIS SUBJECT IN THEIR TESTIMONY.

SCIENCE AND ENGINEERING EDUCATION CONTINUES TO BE A FOCUS OF PARTICULAR INTEREST AND CONCERN TO THIS SUBCOMMITTEE. WE ARE PLEASED TO SEE A PROPOSED INCREASE OF 63 PERCENT FOR UNDERGRADUATE PROGRAMS ACROSS THE FOUNDATION IN THE FISCAL YEAR 1990 BUDGET. HOWEVER, WE NOTE THAT THE PROPOSED INCREASE FOR PRECOLLEGE PROGRAMS IS ALMOST 6 PERCENT LESS THAN THE PERCENTAGE INCREASE SOUGHT FOR THE TOTAL NSF BUDGET. WE QUESTION THE WISDOM OF ANY FLAGGING IN SUPPORT FOR PRECOLLEGE PROGRAMS, WHICH ARE CRITICAL FOR MAINTAINING THE PIPELINE OF NEW SCIENTISTS AND ENGINEERS AND FOR RAISING THE SCIENCE LITERACY OF THE GENERAL POPULATION. WE INVITE DISCUSSION ON THE BALANCE OF NSF PROGRAMS IN SUPPORT OF PRECOLLEGE, UNDERGRADUATE, AND GRADUATE LEVEL EDUCATION.

MR. BLOCH AND DR. POWELL, WE WELCOME YOU BOTH HERE THIS MORNING AND LOOK FORWARD TO OUR DISCUSSION OF NSF PROGRAMS AND PRIORITIES.

Mr. **Boehlert**. Thank you, Mr. Chairman.

It is a pleasure to be here this morning to review once again the outstanding work of the National Science Foundation. I have the greatest admiration for the Foundation and for Erich Bloch. Indeed, I would not be disappointed if Mr. Bloch were elevated—if that is the right word—to the position of White House Science and Technology Advisor, a job we should probably rename "science czar" to keep it in accord with the current nomenclature. [Laughter.]

Also, I should point out that history has taught us that czar is not the kind of position one can keep unfilled for long periods without untoward consequences.

In all seriousness, though, we need that position filled because the Nation's scientific and technological enterprise is in a more perilous state than we generally like to admit. To put it starkly, while the National Science Foundation, in capital letters, is hitting new heights, the national science foundation, in small letters, is crumbling.

I don't think I have to rehearse the distressing statistics here, many of which come from NSF itself. But even more distressing than the statistics themselves is the realization that the NSF budget in no way reflects these harsh facts. Teacher training programs, for example, which are a proven, time-tested means of improving pre-college education, are slated for less than an eight percent increase. No matter what the individuals who make up the NSF say about education, the budget expresses an attitude of, Don't worry; be happy.

Dr. Thomas Pollard, a noted cell biologist who testified at our hearing on setting science priorities, put the matter well. He said:

> No matter how many dollars are available for the elite to do their research at the university level, the country will fail to compete economically and militarily if our basic educational system is rotten.

Those were Dr. Pollard's words.

You have my pledge to continue to get you those important funds for what Dr. Pollard terms "the university elite." I think we need a reciprocal pledge from NSF to help the next generation.

Thank you, Mr. Chairman.

Mr. **Walgren**. Thank you, Mr. Boehlert.

Are there other opening comments?

The gentleman from California?

Mr. **Brown**. I have no statement, Mr. Chairman.

Mr. **Walgren**. The gentlelady from Rhode Island?

Ms. **Schneider**. No comments, Mr. Chairman.

Mr. **Walgren**. Well, let me at this point turn to our special guest for this morning, for the next hour.

Mr. **Boehlert**. Before that, Mr. Chairman, if I could indulge you for one moment, Congressman Ritter, who is a very active member of this subcommittee and is vitally interested in the National Science Foundation, has a conflicting hearing, but he does have an opening statement which I ask permission to have inserted in the record at this point.

I would point out that, hopefully, Mr. Ritter will be able to share some of this morning with us.

Mr. **Walgren**. Without objection, Congressman Ritter's opening statement will be inserted into the record at this point.

[The prepared opening statement of Mr. Ritter follows:]

HON. DON RITTER (R-PA)

OPENING STATEMENT

NSF OVERSIGHT HEARING

MARCH 16, 1989

MR. CHAIRMAN, I'M PLEASED TO BE HERE TODAY TO DISCUSS FY 1990 PROGRAMS AT THE NATIONAL SCIENCE FOUNDATION WITH DR. BLOCH AND DR. POWELL. THE NATIONAL SCIENCE FOUNDATION PLAYS A CRITICAL ROLE ON THE FRONT LINES OF AMERICA'S BASIC SCIENCE AND ENGINEERING RESEARCH EFFORT. WE MAY BE COMPETING WITH INTERNATIONAL POWERS IN TERMS OF CONVERTING BASIC RESEARCH INTO MARKETABLE PRODUCTS, BUT WE ARE UNRIVALED IN BASIC RESEARCH, IN LARGE PART DUE TO THE SUCCESSFUL LEADERSHIP OF THE NSF.

I HOPE THAT THE INCREASE IN NSF FUNDING

WHICH WE PROVIDED IN LAST YEAR'S BILL, AND CONTINUE TO SEE HERE, WILL HELP TO STRENGTHEN AMERICA'S BASIC RESEARCH EFFORTS IN "CUTTING-EDGE" FIELDS SUCH AS HIGH TEMPERATURE SUPERCONDUCTIVITY, PHOTONICS AND FIBER OPTICS, BIOTECHNOLOGY, ADVANCED MANUFACTURING SCIENCES, AND MORE.

BUT AS WE'VE SEEN SO FAR IN THESE OVERSIGHT HEARINGS, THE NSF HAS ANOTHER MAJOR FUNCTION: INVESTING IN THE NEXT GENERATION OF SCIENTISTS AND ENGINEERS. I AM CONCERNED THAT THE SUPPORT FOR VITAL SCIENCE AND ENGINEERING EDUCATION PROGRAMS IS NOT AS STRONG AS THAT FOR OTHER PROGRAMS, AND I HOPE THAT OUR WITNESSES WILL ADDRESS THAT TODAY.

I AM ALSO CONCERNED THAT WE MAINTAIN A

PROPER BALANCE BETWEEN THE CENTERS PROGRAMS AND THE EFFORTS OF INDIVIDUAL INVESTIGATORS. I WILL BE INTERESTED IN OUR WITNESSES' COMMENTS ON THAT.

ON THE WHOLE, THE NSF BUDGET FOR FY 90 IS A STRONG ONE, REFLECTING NSF'S IMPORTANT ROLE IN OUR SCIENCE AND TECHNOLOGY ENTERPRISE. I AM PLEASED TO SUPPORT NSF'S EFFORTS, AND I HOPE THAT WE CONTINUE TO STRIVE TOWARD THE GOAL OF DOUBLING NSF'S BUDGET. THANK YOU, MR. CHAIRMAN.

Mr. WALGREN. We will also insert into the record at this point, without objection, an opening statement by Congressman Terry Bruce.

[The prepared opening statement of Mr. Bruce follows:]

Thank you Mr. Chairman. In the era of tight budgets and little room for program increases, I am pleased to be a part of this hearing reexamining the direction that the National Science Foundation is heading. This agency is responsible more than any other for emphasizing the important progress we need to continue in order that our Nation may enjoy further scientific discovery and in an increasingly competitive global environment.

My vision of America's future is one of renewed competitiveness. It is a future in which once there was a smoke stack industry, now there is a new renovated industry that can provide the world innovative and quality products. To achieve this vision, America must make a systematic investment to secure its prosperity—educating and retraining our people, developing and implementing new technologies, and building the productive capacity from which we will reap rewards in years to come.

Congress and the new administration are both vitally aware of the importance of international competition. We must be willing to make the long-term commitments that are necessary that will allow industry and the scientific communities to grow and expand enriching one another.

I look forward to the testimony of our witnesses today before this subcommittee. Throughout the testimony presented here I hope we can come away with a more focused look at the priorities of NSF. In the past several years, funding for science and engineering education has increased. I am though, still concerned with the limited increase in the pre-college science programs. I firmly believe the crisis we have in scientific education has to be addressed in a balanced approach from the beginning of one's education throughout all stages.

The aging of our science infrastructure, the increased cost of doing scientific research and the levels of support required for adequate instrumentation plaque every research university today. In a recent survey at the University of Illinois, only 30 percent of the existing research and development facilities is suitable for use in the most highly developed scientific research and over 25 percent of that space has been determined to be in need of major repair or renovation. This has become common among our premier research universities today. These concerns need to be evaluated and included in any list of essential items for our long term scientific competitiveness.

I am pleased that Mr. Bloch and Dr. Powell are before this subcommittee today to discuss the important issues before us. Thank you.

Mr. WALGREN. Well, let me recognize the gentleman from Michigan, Mr. Wolpe. He has a special interest in the panel today, but he is somebody that we all look to because of his role on our full committee in years past and his role in the Budget Committee, in particular, a strong voice for science.

The gentleman from Michigan?

Mr. WOLPE. Thank you very much, Mr, Chairman.

I appreciate your providing me this opportunity to introduce one of our panelists this morning, Dr. James Powell, a very distinguished scientist and academician. He has been a member of the National Science Board since 1986.

The reason that I had wanted to make the introduction this morning is that he also happens to be currently president of my alma mater, Reed College, a small liberal arts college in Portland, Oregon, where I had the pleasure of doing my undergraduate work back in the early sixties.

Although small in size, Reed is very large in stature. Among liberal arts colleges, it is number one for producing Rhodes Scholars. In the past 50 years, there are some 29 graduates of Reed that have won that Rhodes Scholarship. I happen to have defied that tradition. The year that I was a senior, I was the nominee. It was the first year in 17 we did not get the Rhodes Scholarship, something that was difficult to live with in that environment. [Laughter.]

Reed is also ranked third among liberal arts colleges for graduating students who go on to get Ph.D.'s, and it is also the third ranking among such colleges in those who go on to get Ph.D.'s in the sciences, a very unusually strong science program in a small liberal arts environment.

Dr. Powell is a graduate of Berea College in Appalachia. He went on to get his doctorate in geochemistry at my other alma mater, MIT. He chaired the department of geology at Oberlin College, where he spent some 21 years as a teacher and later as acting president. He was president of Pennsylvania's Franklin and Marshall College for some eight years and has been a visiting scientist at Oxford University.

Given that very long list of credentials, it is no surprise that Dr. Powell is a well recognized authority in science education. It was a delight for me this morning to have the opportunity to become acquainted with Dr. Powell and also to catch up on the lore of the last lot of years. I graduated from Reed back in 1960.

But it is a pleasure to have him with us today, and I thank you for the opportunity to make this introduction.

Mr. WALGREN. Thank you, Mr. Wolpe.

We appreciate your role in all this area over the past years and look forward to having you with us on the subcommittee as well.

Let's turn, then, to our primary witness, I gather, this morning, Mr. Bloch, the Director of the National Science Foundation. I don't know whether the others will have statements, but we will get to that.

As you know, Mr. Bloch, your written statements and anything you would like to submit in writing will be reproduced in full, and you can feel free to emphasize and underscore points in whatever way you would like to make them most effectively.

So welcome to the committee. We appreciate your being here.

STATEMENT OF ERICH BLOCH, DIRECTOR, NATIONAL SCIENCE FOUNDATION

Mr. BLOCH. Thank you very much, Mr. Chairman.

Dr. Powell has been duly introduced, so I don't have to do that, but he represents here the Board itself, the National Science Board itself, and he has a few comments after I have completed. Also, Dr. John Moore, deputy of NSF, is at the table.

I appreciate all the comments from you, Mr. Chairman, as well as from Mr. Boehlert. I thought Mr. Boehlert was a friend of mine. I am not sure any more after hearing his opening comments. [Laughter.]

Mr. WALGREN. Well, you know how it is in this town. If you want a friend, get a dog. [Laughter.]

Mr. BLOCH. Good advice.

Mr. Chairman, for the first time ever, NSF is operating under a five-year authorization. You mentioned that yourself a minute ago. In combination with the commitment to double the NSF budget by 1992,[1] which was made by the Reagan Administration and affirmed by President Bush in his State of the Union address, this authorization has provided a degree of stability in planning that is new to us and is very helpful. I appreciate the leadership of this committee and its chairman in making this possible.

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[1] Mr. Bloch indicated that correct date is 1993.

NSF is here to serve the needs of the Nation in the science and technology area, not the needs of scientists and engineers but the needs of the Nation. That is fundamental, and it underpins the changes that we have made at NSF in recent years. We see NSF as a catalyst for change, seeking better ways to respond to national issues and goals.

In past years there was a tendency for both Congress and the academic world to see NSF as a passive agency, just waiting for proposals to come in the door, concerned only with science and the academic community. That image, if it ever was true, is out of date.

NSF today is deeply concerned with engineering as well as science. We stress education and human resource development, the fastest growing part, by the way, of the Foundation's budget, and I have more to say on that in a minute.

We are committed to bringing universities and industries more closely together, so that knowledge moves smoothly from university laboratories to economic payoff.

The budget request for fiscal year 1990 is $2.149 billion, or about a 14 percent increase over this year's appropriation. It is about five percent less than the authorized level without facilities. We all wish the number could have been higher, but we all also know about our budget problems.

In this situation, the budget request is a very strong response to the needs of the Nation and reflects the difficult choices we have had to make.

There are differences between the authorization levels and the budget request for specific activities. But, overall, the request is very close to the distribution suggested in your authorization, as you will see when you examine the details.

We continue the emphasis of the past few years on three major themes: a very strong effort in education and human resources, a strong disciplinary research base, and an expanding program of group and centers research. I will discuss each of these and highlight the differences between request and authorization.

Let me talk first about education and human resources. It is our top priority. We all are aware of our educational problems, and you have pointed that out a minute ago, and so has Mr. Boehlert. The President has proclaimed his intention to do something about them, and so have many governors and other State and local officials. It is time to take effective action.

Nothing will do more in the long run to assure our economic success in a competitive world, our natural security in a dangerous world, and the living standards of our people than focus on education and human resources.

Our effort at NSF will rise by about 22 percent, the largest increase among the three strategic themes. Part of this increase will support efforts to broaden the human resources base on which the Nation can draw, seeking to enlist larger numbers of women, minorities, and other groups that have not historically contributed large numbers of scientists and engineers.

We have to find ways to reach these students, because the Nation needs far more scientists and engineers than we can recruit without them. By the end of this century, about 85 percent of the net new entrants to the labor force will be women, minorities, or new immigrants. There is no way we can do without the contributions of these people to our scientific and technological future.

About 55 percent of the human resources effort is in the programs that we specifically label "science and engineering education." Those programs include such activities as materials development, pre-college teacher programs, and undergraduate instructional equipment.

But many other programs are administered through other parts of the Foundation. Special programs for undergraduate students, for women and minorities, for undergraduate faculty, and special curriculum development efforts in chemistry, biology, and computer sciences are included in these efforts.

Taken together, the education and human resources effort will amount to $347 million in 1990. That is an increase of $62 million from last year. It continues a long trend that has seen spending for this category rise ten-fold since 1982. NSF has a real commitment to this area.

In 1982, the low point of science education at NSF, we spent $3.8 million on pre-college programs. Next year we will spend $129 million for teacher programs, materials development, informal education, and the Young Scholars program.

In 1982, there were no undergraduate programs at all. Next year our undergraduate efforts will total $105 million. Part of this will be administered by the Science and Engineering Directorate,[2] but the majority is provided by the research directorates to support student research, special undergraduate faculty programs, curriculum development, and other areas.

Graduate education has always been a part of NSF's programs, but here, too, there has been important growth. The number of graduate fellows will nearly double between 1987 and 1992, with special emphasis on minority students and for women in engineering.

The disciplinary research base will increase about 11 percent, or $131 million. This second thrust area remains the largest part of NSF's effort, accounting for about 60 percent of the total. In fiscal year 1990, it will support about 20,000 persons in 1,500 institutions, working in every area of science.

High priority areas next year will include genetics, superconductivity, microscale chemical processing, software engineering, and many others. There will be special emphasis on materials research and high performance computing and in three environmental areas: global change, Antarctica, and biodiversity.

The global change initiative is especially interesting as an example of the interagency cooperative approach we are encouraging. You have copies of the report of the Committee on Earth Sciences, "Our Changing Planet," that describes the activities.

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[2] Science and Engineering Education Directorate.

In short, we will cooperate with NASA, DOE, the Geological Survey, and many of the other agencies in this effort, which amounts to about $190 million in 1990. Our part of that one is about 25 percent.

A second major environmental effort, and one that causes the most apparent change in the budget, is in the Antarctic program. The request for the Antarctic program is $156 million, about six percent above the authorized level.

Following a fatal accident in 1986 in Antarctica, I initiated a thorough review of health, environment, and safety issues by a special panel chaired by former astronaut Russell Schweickart.

We have now begun a major effort to act on the panel's recommendations. This year the request includes $10 million to start on the most urgent problems, including waste management, environmental monitoring, and improved air traffic control and communications.

Our concern with environmental problems in the Antarctic is evidenced most recently by our response to the shipwreck and oil spill from an Argentine naval vessel carrying tourists to Palmer station. Our scientists rescued more than 200 persons from the ship and minimized the oil spillage to the limit of their abilities.

Biodiversity is the third research area that is important to the environment. The world has a serious problem in the loss of genetic diversity, which can have an adverse effect on economic development. We propose to start this effort with $11 million in 1990.

The third strategic theme is centers and groups, an expanding area that reflects the need to tie universities and industries more tightly together. It is a continuation of a direction we took in 1983 when we began planning the Engineering Research Centers.

This theme emphasizes a way of organizing research rather than particular research areas. The research in centers and groups is just as basic and shows the same diversity as work supported in the disciplinary programs. The difference is that organizing on a larger scale allows more interdisciplinary work, and getting industry, and sometimes national laboratories, involved helps to make sure that new knowledge actually gets used.

Centers have also been a very good way to leverage scarce Federal research dollars with industry money, as well, on more than a dollar-for-dollar basis in the engineering centers program. And we are expecting the same in the science and technology center arena.

Overall, this area will grow by almost 18 percent, although the actual dollar increase, about $57 million, is obviously smaller than the increase for basic disciplinary programs or the education and human resources area I discussed before.

With part of this increase, we will establish eight to ten new Science and Technology Centers in addition to the eleven which were started this fiscal year. This continues the direction we began to take in 1983, when the first report recommending establishing the Engineering Research Centers was received.

Even with this growth, however, centers of all sorts—the ERCs, the STCs, the minority centers, plant science and biology centers, earthquake centers and materials research laboratories—remain a small part of the Foundation. I do not expect it to grow beyond about 10 percent of the total, even as the Foundation budget doubles in the next few years.

In the budget request, the figure for science and technology centers is well below the level authorized. As you will recognize, however, this difference is the result of factors that we can discuss later on.

Let me spend another minute on the differences between authorization and request. I mentioned already some of the differences. There are minor variations between the authorization and the actual 1990 request.

Overall, the request [3] is about 5.6 percent below the authorized level. This is reflected in most activities. The major directorates show reductions of up to about eight percent from the authorized levels. The slight variations between the directorates reflect specific program priorities.

The Computer and Information Science Directorate is an exception to this general statement. It shows about a two percent increase. The special emphasis on this relatively new directorate reflects the overwhelming importance of computers, semiconductors, and related industries to our economy and our international competitiveness. It will also allow greater effort to develop our human resource base in these disciplines with special programs for undergraduates and minorities.

The authorization bill provides a large amount, $125 million, to start a facilities program this year. As you know, however, no money was appropriated for this purpose, and none is requested in the current budget. We are proceeding instead, as instructed, to plan an effort for possible future implementation.

To accomplish this, I have established a Research Facilities Office, and we have developed a schedule to produce the requested study and plan by June 15, 1989. I am confident that we will meet this schedule.

Mr. Chairman, you mentioned before, and I know that your committee is interested, as we all should be, in the problem of setting priorities among science and technology programs. I have spoken frequently of the need to do this; so have many others.

NSF takes priority setting seriously. It goes on all during the year, in a careful process of budget planning that is based on strategic considerations and an explicit long-range plan.

Priorities are set at many different levels. It is easiest at the level of the individual discipline, where committees of experts make judgments on the basis of common points of view. We could liken this to comparing apples with apples.

Judgments between disciplines are more difficult, more a matter of comparing apples and oranges, if you will. We rely on groups with broader perspectives, and especially the National Science Board, to help in this matter. The criteria for deciding are more varied: the effect on human resources, on industrial competitiveness, on the development of disciplines, on geographic distribution, and many more.

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[3] Request for Research and Related Activities.

We do this as systematically as we can, and usually in increments. Large changes are almost never made all at once, but rather over a number of years, so that the effects can be monitored and corrections can be made when necessary.

Science and Technology Centers are a good example of this. The effort grew out of our report in 1983, as I already mentioned. Experience with these centers led eventually to the Science and Technology Centers that we began last year. But it has been a gradual, incremental process, spanning more than six years to date.

In all of this it is important that we keep the national interest clearly in mind, that our program choices are made so that the tax dollars we spend are best used to secure the long-range benefit of our Nation.

Mr. Chairman, the Foundation's programs are designed to be both responsive to the Nation's needs and also to provide the stable support that research programs must have. Our three strategic themes which I outlined over the last few minutes give us a way to balance the need for stability with the need for change, and to balance the need for new knowledge today with the need to invest in the people who will provide tomorrow's new knowledge.

I believe these programs are a wise investment for the American people and that they justify the confidence you indicated when you enacted our authorization bill last year.

I would be pleased to respond to your questions, but I think Dr. Powell would make a few additional remarks.

[The prepared statement of Mr. Bloch follows:]

TESTIMONY OF
MR. ERICH BLOCH
DIRECTOR, NATIONAL SCIENCE FOUNDATION
BEFORE THE
SUBCOMMITTEE SCIENCE, RESEARCH AND TECHNOLOGY
OF THE
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
UNITED STATES HOUSE OF REPRESENTATIVES
MARCH 16, 1989

MR. CHAIRMAN AND MEMBERS OF THE SUBCOMMITTEE:

I would like to take this opportunity to discuss the Foundation's FY 1990 programs. These activities continue to emphasize the people, knowledge, and partnerships that are essential to scientific discovery, technological innovation, and national economic and social progress.

CHANGES IN SCIENCE AND TECHNOLOGY POLICY

In the past several years there has been a significant change in the way the Administration, Congress, and the country view the role of science and technology in national and global affairs. Congress and this Committee have been instrumental in drawing attention to the connection between our nation's science and technology investment and its general well-being. The Foundation has played a major part in re-shaping the federal role to meet our changing environment.

As a nation, we recognize that in many areas we can no longer take our world leadership for granted. That is equally true with regard to product competition in the world marketplace and also in research and technology. The world is highly competitive, and our ability to meet this competition is being seriously challenged in many areas. Where American technology was the best in the world in nearly every field, now other nations are closing the gap, becoming our equal, or -- in certain fields -- drawing ahead of us.

We also recognize that knowledge has become a significant economic resource -- perhaps surpassing in importance traditional natural resources and labor costs.

A consequence of these changes in global and economic dynamics has been an increased awareness of the importance of technological innovation in making the country internationally competitive, and the long-term effect of investments in education and research on our economic and general welfare.

NSF has changed in recognition of these developments. Where we once could operate with little regard to issues of national concern, we now focus our efforts and our role with those issues in mind. Where we were once more passive, responding primarily to the needs of science as expressed by scientists, we are now catalysts for change -- instigating scientific efforts and cooperation needed for broader progress. Where our relationships at one time were primarily with the scientific academic community, they now include the engineering community, industry, and the teaching profession, as well.

Due to Congress' and the Administration's focus on NSF and the resulting increases in our budget, NSF is now a more important participant in federal science and technology efforts. Our programs focus on strategic areas that are directly related to long-term scientific achievement. These efforts have resulted in significant changes and accomplishments.

NSF funding enables scientific and engineering research at the frontier of knowledge through our support of university basic research and its associated infrastructure, which are our primary source of research knowledge and trained personnel. For example, an explosion of research results in high temperature superconductivity followed important breakthroughs made by NSF supported research teams. Another example is supercomputers. NSF established the first program providing widespread academic access to supercomputing capacity through its national supercomputer centers. That access has led to significant achievements such as the first mapping of the common cold virus and major progress in computer visualization techniques, for example. Today there are numerous other academic supercomputer facilities that followed on the heels of NSF's program, and that augment the availability of this important new resource.

NSF has placed human resources development at the top of its list of priorities. Our programs are designed strategically to increase the numbers of young people concentrating on science and engineering and to improve the quality of the education they receive. Well trained scientists and engineers are indispensable to our national efforts; but American students have not been pursuing careers in science and engineering in sufficient numbers to meet future needs. To educate our students in the sciences, our teacher population needs a better educational base, more recognition of its critical mission, and new entrants to fill future needs. Unless we do a much better job at attracting students and giving them the best possible training, we cannot meet the challenges we face in international competition.

We have established programs throughout NSF that address education and the human resource issue in many different ways. There have been dramatic increases in support for education at all levels and efforts to broaden participation of underrepresented groups, such as women and minorities; and underrepresented institutions, such as undergraduate colleges and others. Support for education and human resources has grown from about 3% of the NSF budget in 1982 to over 15% in 1989. Another tangible result of these efforts is that the numbers of people -- students at all levels, teachers and research faculty, and investigators -- supported under NSF programs, have more than doubled over that period.

The Foundation has also challenged the traditional ways research is organized and carried out in an effort to stimulate the transfer of knowledge and promote cooperation of the participants. Our emphasis on centers and groups -- together with supporting individual investigators -- has stressed multidisciplinary research and topics important for the sciences and engineering and relevant to economic growth and development.

The center concept, which encourages strong industry participation and interaction, has created an entirely new research culture at universities. In fact, a number of centers have been established by academic institutions with the help of state and industry funding, as a result of relationships developed in developing unsuccessful but otherwise viable proposals for NSF support.

New Relationships

As NSF's role in education, science, and engineering changes, new relationships need to be forged.

Industrial participation in many of our programs is important not only for the monetary support that participation provides, but because it improves communication between important sectors of our society. Initiatives such as the Engineering Research Centers and Science and Technology Centers, the Industry - University Cooperative Research Centers, and the Presidential Young Investigators program serve to facilitate knowledge transfer and establish new working relationships that hasten progress and improve focus on common interests.

We have had conversations with the National Governors Association, individual Governors and state administrators to encourage increased coupling between NSF and state financed programs for a more synergistic relationship.

International relationships are increasingly important. The rising cost of research, budget realities, and the increasing strength of our trading partners in the research arena have made it vital to gain access to their research competence and pursue joint efforts in areas of mutual interest. Areas such as astronomy, physics, cosmology, earthquake research, and global environment are particularly important for such relationships.

Many of our programs also involve cooperation with other agencies. The U.S. Global Change Research Program is an especially interesting example of the interagency cooperative approach we are encouraging. Education is another example. We are pursuing cooperation in this area with the Department of Education as we look for ways to make the President's commitment to education more effective within probable budget constraints. For example, we have jointly supported children's television programming, such as "3-2-1 Contact"; and various national education assessment efforts, such as the National Assessment of Educational Progress.

Continuity and Future Planning Environment

Change is a necessary condition for progress and growth. Changes in our perspective on the role of science and technology and changes in the way NSF carries out its traditional role in promoting the health of science have provided a fresh focus, set the stage for a series of new initiatives, and invigorated existing programs.

In addition to change, continuity, stability, and a predictable planning environment are important. Research results are not usually achieved in short periods, and many research problems have very long horizons. Social and economic problems are many years in the making and require sustained efforts to correct. New challenges continually arise, and we need to be prepared to respond to them.

The commitment by the Administration in the 1989 and 1990 Budgets, and the Congress' commitment in the 1989 Authorization Act, to double the Foundation's budget by 1993 go a long way toward providing that stable planning environment. It will allow us to focus on building the research infrastructure and emphasizing those areas most related to national challenges and opportunities.

Challenges and Opportunities

The Federal research support effort for FY 1990 again emphasizes as one of our highest priorities, the need to strengthen U.S. technology and competitiveness through research.

Global Environment. As important as our response to the technological challenges of a global economy may be, so too is our understanding of the global environment and the effects of man-made influences on it. The issue of global change is of obvious critical concern. It illustrates - perhaps better than any other example - the enormous scale, complexity, and multidisciplinary nature of many research areas. The NSF part of the overall FY 1990 U.S. Global Change Research Program is 29% of the total. Our program supports the geosciences and other efforts that seek to understand how the earth functions as an interconnected system.

Research in the Antarctic area, uniquely important to our understanding of several phenomena related to climatic change, is one example. A major initiative in Biodiversity, focused on understanding the extent and environmental implications of the loss of species and habitats, is another. These activities require not only direct support for research, but large-scale operations and logistics.

Materials. A rapidly expanding scientific knowledge base is providing significant opportunities to advance the state of the art in materials processing. Everyone is aware of the rapid developments in superconductivity that promise important technological advances and economic benefits. Materials research is also having great impact on the development of applications involving semiconductors, submicron circuitry, microelectronic technologies, surface technology, composite materials, and other areas.

New Research Tools. The exploitation of opportunities for new research discoveries with important economic potential is often paced by the availability of special tools that extend the limits of computational capacity, experimental conditions, and measurement.

For example, forefront research in a number of physical and biological science areas depends on scientific access to high magnetic fields.

Research efforts in high performance computing and communication will advance computer and information science and engineering, as well as serving the broader needs of investigators across all disciplines.

The pace of technological development depends on the knowledge generated by research. Breakthroughs in critical areas are requiring an increasingly expensive multidisciplinary and capital intensive approach. We must make the necessary resources available for basic research, or face the negative consequences for productivity, competitiveness, and economic progress.

Priorities

A few words about priority setting should be said. Within NSF there is a continuing need to set priorities across fields of science and engineering and among many competing initiatives of importance and high merit. This is no different in principle from the problem faced by Congress in considering programs across all areas of national responsibility. We cannot accomplish everything within available resources, and choices must be made.

At NSF, overall priority setting is accomplished through a broad framework of information gathering and strategic planning. The Foundation's Long Range Plan for FY 1989-1993 was published last summer, and we have already begun re-examining the assumptions and environment upon which it was based. Our programs for FY 1990 were developed in the context of that long range plan, and our priorities flow from its broad objectives and themes.

Our planning and priorities involve information, advice, and expertise from a large range of people and organizations from all sectors. The process involves disciplinary advisory committees, academic and National Research Council task groups and committees, academic and industry associations and committees, our own professional staff, and the National Science Board. Planning, priority setting, and budgeting are done within the context of, and take into account, national goals, the health of science and education, scientific needs and opportunities, and many other factors.

Within our directorates, hard choices are made among highly meritorious projects. These choices are also made within the context of overall Foundation priorities and objectives, and involve an extensive merit review process. Each directorate also engages in a broadly based advisory process that assists in overall priority setting within disciplines.

There are no easy choices, and priorities must be continually reassessed in light of new developments and opportunities. In the long run, however, the Foundation's first priority has been people, both in developing human resources and in research support. Our second priority has been the instrumentation needed for education and research. Our third priority remains the larger, shared facilities that provide access to advanced instrumentation and computational capabilities.

Our priority setting is guided, as well, by national objectives as articulated by the federal authorization and budgeting process, in which these oversight hearings play a significant role. The Foundation's programs for FY 1990 are consistent with the framework provided in our recently enacted five year authorization. It should be noted that, pursuant to Title II of the NSF Authorization Act, we established a Research Facilities Office (RFO) in December 1989. The Office is responsible for managing the development of the Academic Research Facilities Modernization Program, as directed in the act. An assessment of current facility capacity and future needs is being conducted as part of determining a detailed program plan.

NSF FY 1990 BUDGET

The FY 1990 budget request for the National Science Foundation is $2.149 billion, an increase of 14% above FY 1989.

As previously noted, this request is consistent with NSF's doubling strategy as articulated in the President's Budget Message and reflected in the Foundation's current authorization. The budgeted programs support needed growth in the nation's science and engineering research and education efforts. We believe it also reflects the growing awareness of the importance of U. S. science and technology in responding to national and global challenges and opportunities.

Our FY 1990 programs again emphasize three thrust areas:

- **Education and People** -- There is an urgent need to address the human resources issue across all parts of the educational pipeline.
- **Knowledge generation** -- We need to strengthen the traditional disciplinary research base and the facilities that support it.
- **Multidisciplinary Cooperation** -- Our group and centers research programs promote new partnerships in attacking problems and exploiting new knowledge.

PEOPLE: EDUCATION AND HUMAN RESOURCES

In FY 1990 we plan over $347 million for support of education and human resource development. This is an increase of almost 22% over FY 1989.

Education and Technical Personnel

Support for education and human resources continues to be one of our highest priorities. The nation's science and technology efforts ultimately depend on an adequate supply of highly trained and educated people.

Last year I presented some striking facts that bear repeating:

- Less than 20% of high school sophomores are interested in careers in natural sciences or engineering.
- Only 1 in 20 students who go on to college receive baccalaureate degrees in science or engineering.
- Less than a third of them continue training; and only a quarter of those who do, eventually receive doctorates.

Thus, from a population of 4 million high school students, we can expect only about 200,000 baccalaureate scientists and 10,000 doctorates. (Figure 1) Past trends suggest that demand for scientists and engineers will increase for years to come. (Figure 2) With the number of college age students dropping steadily, we face a potentially serious shortage of technical personnel unless a greater proportion of the student population is attracted to science and engineering.

Our approach in supporting education and human resources has been wide-ranging, and involves efforts by all parts of the Foundation.

Our emphasis on this issue has resulted in significant increases in the support of education, especially in pre-college and undergraduate areas. NSF support of individuals throughout its programs has increased substantially, as well. (Figure 3)

The Foundation's precollege programs are the largest component of our education and human resources effort. Pre-college activities will again emphasize teacher preparation and instructional material development, especially in middle school mathematics.

NSF Pre-college support has increased dramatically since 1983. Nevertheless, the NSF role in pre-college education is very small in relation to federal and state support for education, and focuses only on science and mathematics. We can lead and stimulate others to lead and to innovate. The States - which bear the principal responsibility for education - must step forward with renewed efforts in this area. We need to continue to encourage partnerships among the state, local, and private players concerned with responsibilities in these areas.

Pre-college science and mathematics education has a potentially large impact on the long-term prospects for the recruitment and retention of scientists and engineers. While today's efforts in this area pay off sometime in the next century, we also need to attract more university and college students from today's cohorts.

One way of encouraging more students to pursue scientific and engineering careers is through the improvement of undergraduate education. Such programs are another area of NSF emphasis. The

Foundation has developed a comprehensive range of undergraduate programs that, in FY 1990, would increase by over 62% to almost $105 million. These efforts involve programs across NSF and include support for student research, faculty enhancement, course curriculum development, and instructional instrumentation. We have also focused significant efforts on broadening participation of groups and performers now underrepresented in science and engineering.

Attracting and retaining minorities and women in science and engineering means overcoming special and longstanding problems. Yet, changing demographics indicate that underrepresented minorities and women will make up a much larger proportion of student populations and new workforce entrants in the next twenty years than today. It essential to look to all segments of our population for the scientists and engineers we need. NSF has increased and added new programs in this area, such as Research Careers for Minority Scholars; Career Access Opportunities for Women, Minorities, and Disabled; Minority Research Centers of Excellence; and other targeted programs.

NSF POSITION ON SCHOLARSHIP BILLS

I want to comment on several bills proposed to establish undergraduate scholarship programs. I commend Members of this Subcommittee for their initiatives in this important effort to provide financial support and increased prestige to attract young people, who are considering science, mathematics, and engineering careers.

Within NSF's undergraduate science education activities, which I mentioned earlier, we have designed programs to have the broadest possible impact on students in all disciplinary science fields. In this way, we believe that NSF is increasing support for, and achieving a balance in funding of, undergraduate science education activities.

The Administration soon will submit its science scholarship proposal to Congress, which has similar objectives as the legislation introduced by Members of this Subcommittee. I support this Presidential initiative to create a "National Science Scholars Program" within the Department of Education and hope the Congress will move expeditiously to enact it.

KNOWLEDGE GENERATION: DISCIPLINARY RESEARCH AND FACILITIES

A primary focus of both federal investment in R&D and NSF support is university-based basic research and capacity. Our FY 1990 plans would include more than $1.3 billion for disciplinary research and the facilities that support it, an increase of 11% over FY 1989.

U.S. universities and colleges are the major performers of basic research and the primary source of our technical workforce. The knowledge produced by the university-based research system is the primary fuel for innovation and, ultimately, economic strength. However, the need to re-emphasize the role of university-based research is increasingly apparent.

Trends in Support

I have noted before that the NSF research and related appropriation in constant dollars has been almost level for several years. (Figure 4) Related trends in the overall federal budget are significant:

- Federal support for basic research, in constant dollars, has increased little over the past twenty-five years, in relation to total R&D spending. (Figure 5)
- Within civilian R&D, the share of federal support going to universities and colleges has been falling, even though the dollar amount has increased since 1980. (Figure 6)

These trends are significant because it is basic research performed at universities and colleges, including the various physical science and engineering programs included in the NSF appropriation, that is of primary importance in fueling industrial competitiveness and understanding the global environment. We must invigorate those programs and fields of support where the challenges and opportunities are greatest.

We previously highlighted broadly-based efforts in multi-disciplinary research focusing on global change, biodiversity, materials, and high performance computing. Continued growth is also requested in other high priority areas such as genetics, mathematics, microscale chemical processing, and software engineering.

It is also important that we address the need to increase the size of NSF project grants, including the need to boost funding for small-scale instrumentation.

The FY 1990 Budget includes renewals and major upgrades for hardware and supporting systems at the five supercomputer centers and expansion and improvements of NSFNET operations and service.

The need for better access to high magnetic fields for research in many areas of the physical sciences is vital. Higher magnetic fields than are currently available would significantly enhance progress in several areas, including superconductivity. Many other nations have upgraded their magnetic field capabilities. Our 1990 program calls for a new facility -- the National High

Magnetic Field Laboratory -- to meet the needs of U.S. researchers.

The character of U.S. activity in Antarctica has changed from expeditionary to permanent scientific presence. With this change has come a recognition that safety, health, and environmental concerns must be addressed in a serious way. Our request includes a major, multi-year initiative to improve those conditions in the region.

MULTIDISCIPLINARY COOPERATION: CENTERS AND GROUPS

We have stressed the importance of cooperation among the various players in the research enterprise and the economy as a necessary element in promoting technological innovation. Progress in many areas of science depends on collaboration between investigators from different fields and between industry and universities.

NSF has been a leader in developing new ways to encourage this cooperation. Our group and centers research programs have promoted new partnerships and cooperation among the players. They have encouraged multidisciplinary cooperation among individual investigators and the sharing of costly research tools in addressing large and complex research problems. They have provided a setting that forges linkages between universities and industry, and between federal and state government. They have created unique educational opportunities for many undergraduate, graduate, and postdoctoral students.

The university-industry cooperation fostered by the centers concept has included significant industrial participation in NSF supported programs. This has meant more resources focused on university research in the form of industrial participation. We estimate that over $300 million in industry contributions was generated in direct support of all NSF programs in FY 1988, about a third of which was cost participation in centers and group research.

Support for research centers and groups would total $376 million in FY 1990. This includes funding for 8-10 new Science and Technology Centers, and additional new centers in several other established areas, including Engineering Research Centers, Comprehensive Regional Centers for Minorities, and the Industry/University Cooperative Research Centers.

I want to address the continuing concern of those who feel that support for centers has been at the expense of support for individual investigators.

Through the centers programs we have encouraged multidisciplinary and organizational linkages that provide new approaches to research and using research knowledge. We believe these linkages provide a healthy diversity and serve to complement traditional, single-investigator initiated research. They often create opportunities for investigators to work in ways that can enhance individual creativity. They do not and will not replace individual research projects as the primary mechanism of NSF support. The number of individual investigators supported by NSF grants continues to increase and will be a continuing priority. Focusing on the organization of research should not down-play a fundamental objective of NSF: to support the best research performed by the best people. This has always been our primary concern, be it by individuals, in groups, or centers.

Salaries

Finally, I want to comment on one aspect of the human resources issue that hits close to home. A growing problem exists across government in attracting high caliber scientists and engineers to the federal workforce. Government salaries are no longer competitive with private sector and university salaries for senior people in many fields of science and engineering.

In order to carry out our programs, it is essential that NSF be able to attract senior researchers to manage them. Salaries for full professors at major private research universities now average $90 - 100 thousand in the natural sciences and engineering. Public universities are not far behind at $75 - 90 thousand.

Some individuals are willing to take a pay cut in order to fulfill what they consider to be a public service objective. But we cannot depend on individual philanthropy to run major federal programs; nor should we have to. We believe that in order to remain an organization of excellence, a new mechanism must be found to solve the basic problem of adequate compensation. We must be able to compete on a level field for talented scientists and engineers.

SUMMARY

The National Science Foundation programs for FY 1990 will contribute in important ways to strengthening U.S. technology:

- Through the efforts of highly trained and educated **people** from all segments of our population;
- Through the **knowledge** generated by university-based research in all fields of science and engineering;

- Through a diverse research environment, emphasizing multidisciplinary cooperation and participation of all research sectors.

Our nation's continued commitment to significant long-term investment in these essential elements of our research efforts will ultimately determine our success in exploiting technological opportunities, maintaining economic competitiveness, and meeting environmental and other challenges.

Congress and this committee has been instrumental in promoting the importance of education and research to our national interests. I know we can count on your continuing support.

PERSISTENCE OF NATURAL SCIENCE AND ENGINEERING INTEREST FROM HIGH SCHOOL THROUGH PH.D. DEGREE

(The Pipeline)

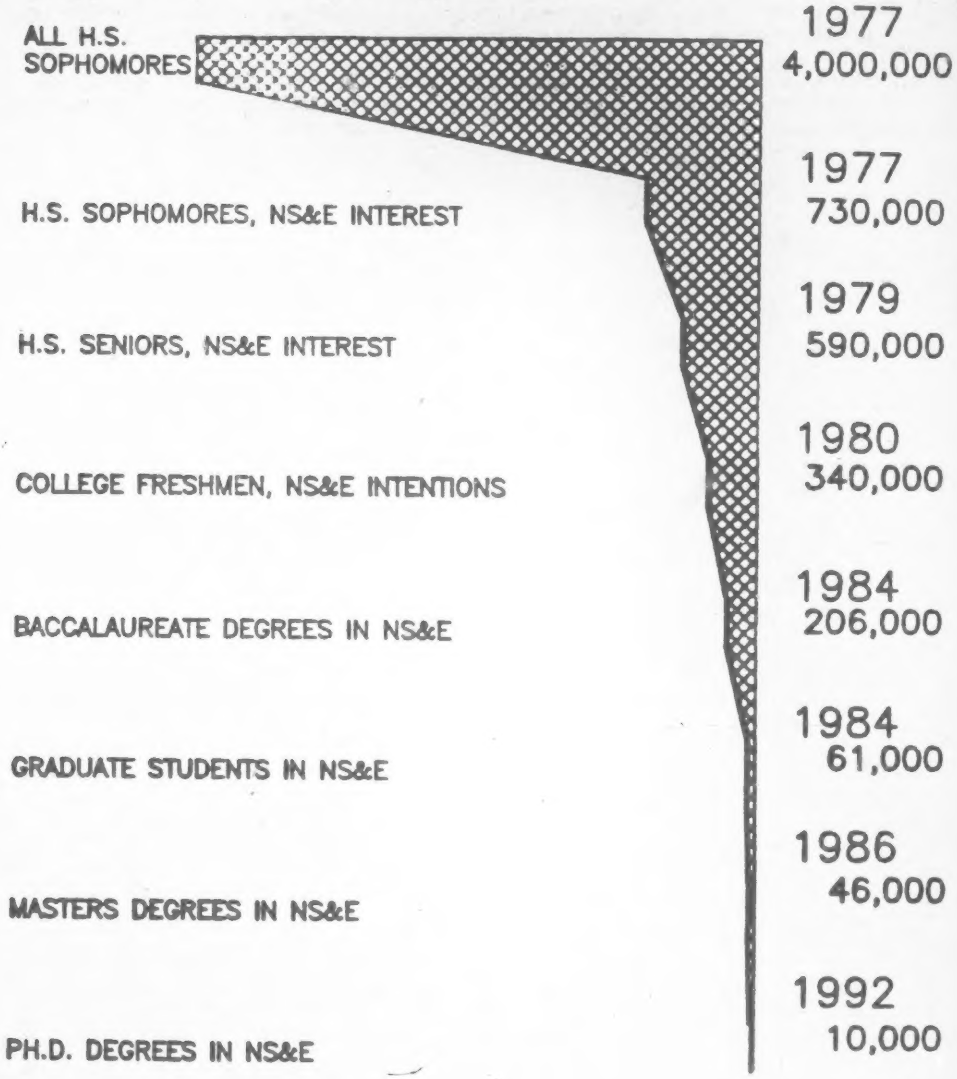
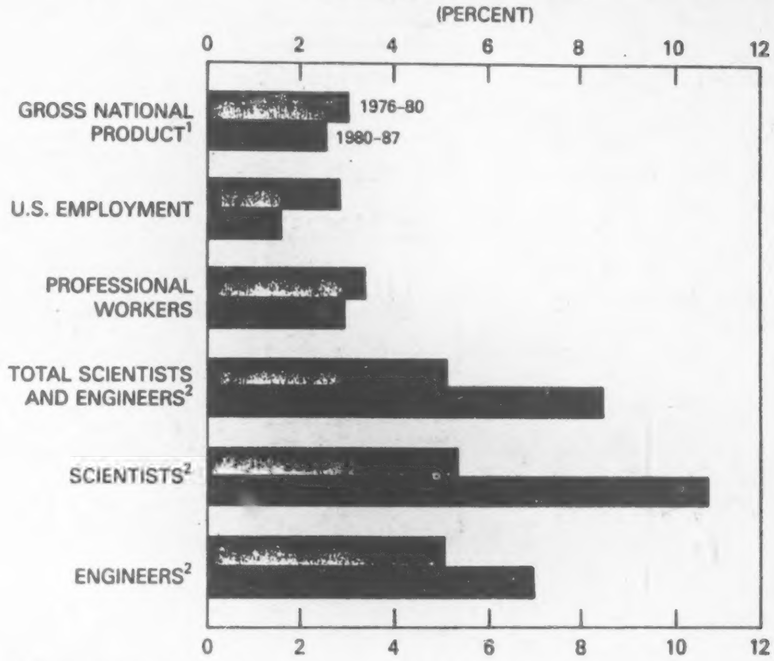


Figure - 1

AVERAGE ANNUAL GROWTH IN SCIENCE AND ENGINEERING EMPLOYMENT AND OTHER MANPOWER AND ECONOMIC VARIABLES



[1] BILLIONS OF 1982 DOLLARS.
[2] DATA REFLECTS 1976-80 AND 1980-88.

SOURCE: NATIONAL SCIENCE FOUNDATION, SRS.

Figure - 2

NATIONAL SCIENCE FOUNDATION
SUPPORT FOR HUMAN RESOURCES

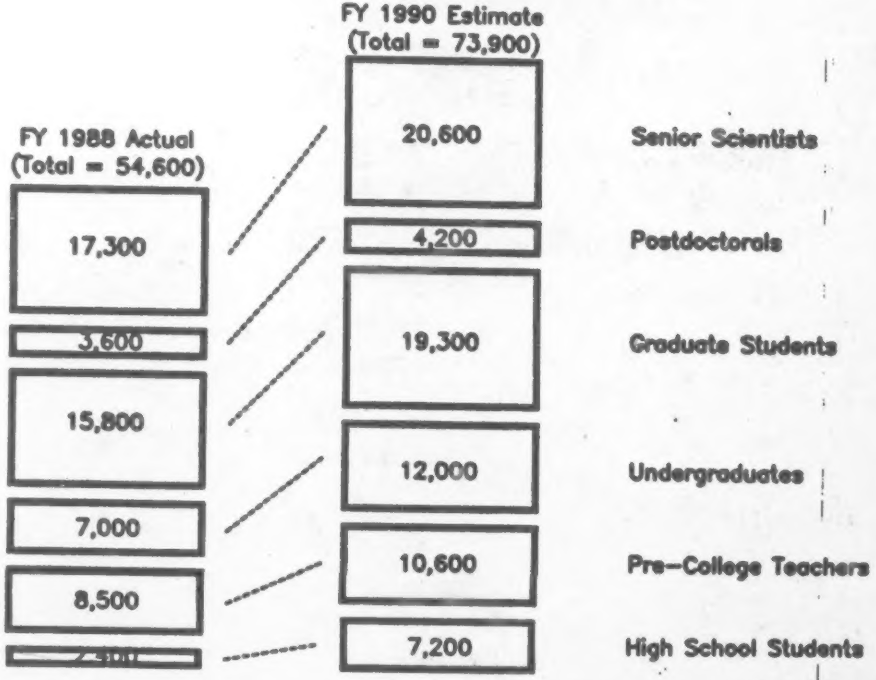


Figure - 3

RESEARCH AND RELATED ACTIVITIES
CONSTANT DOLLAR BUDGET TRENDS
FY 1985 - FY 1990

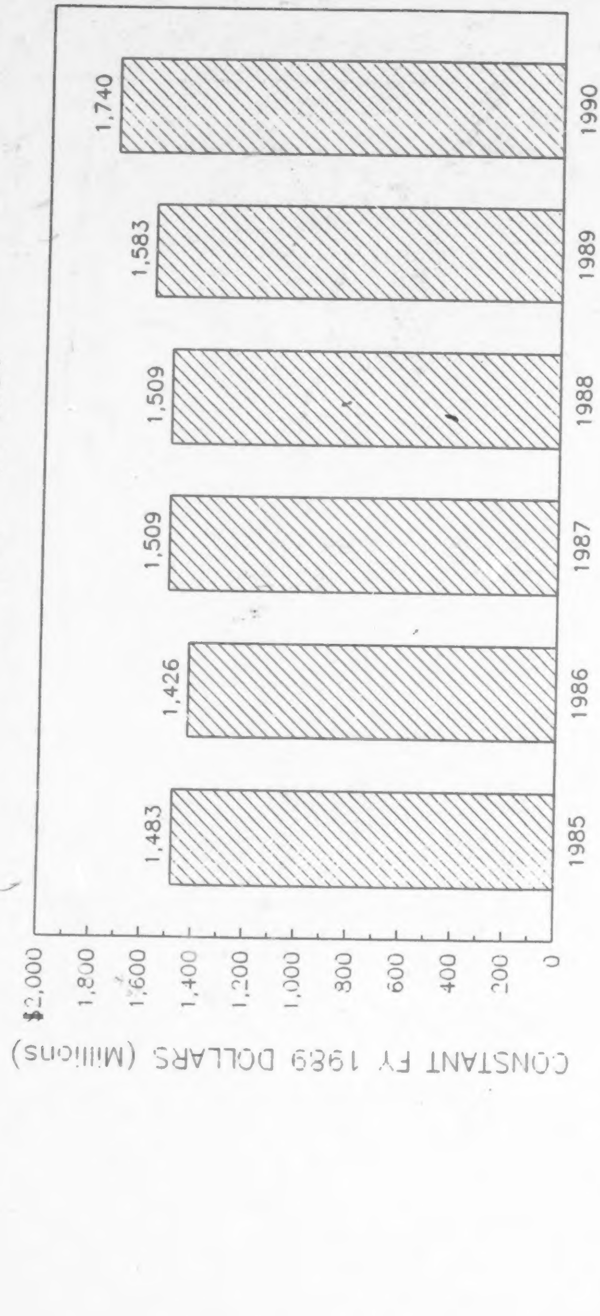
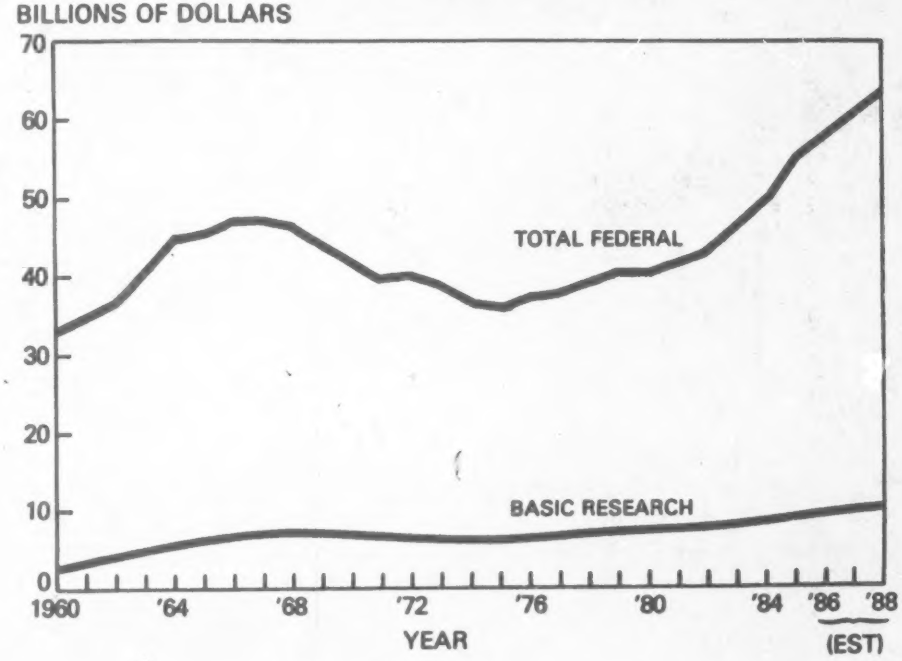


Figure - 4

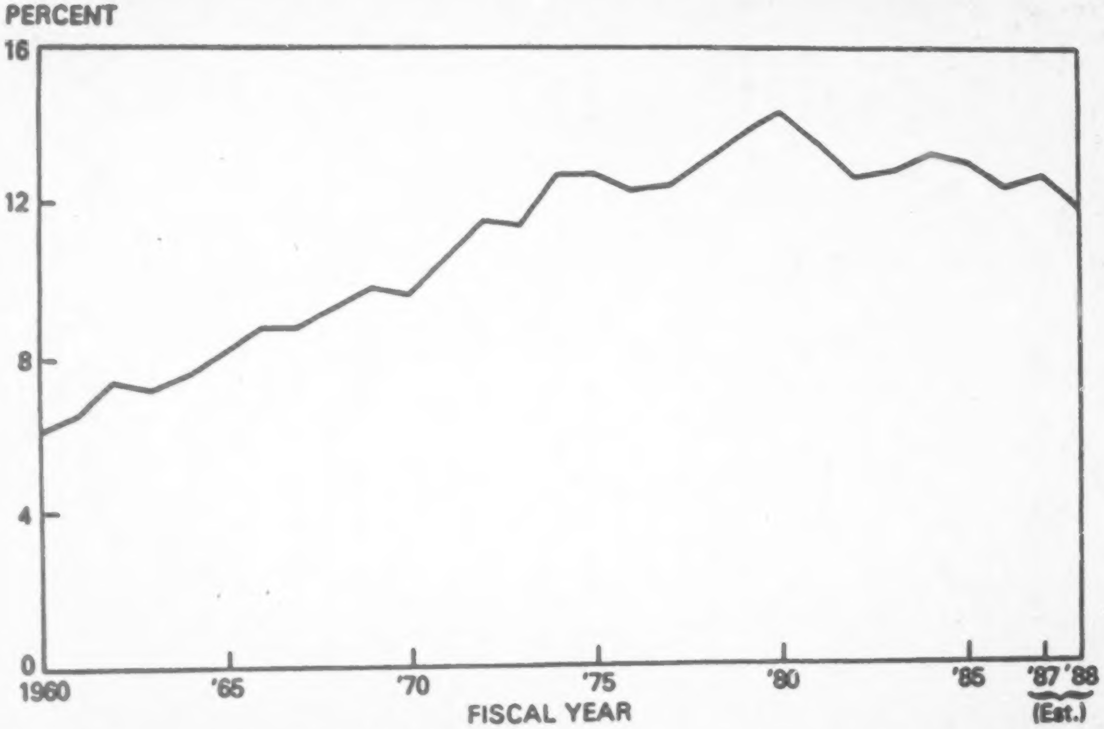
TOTAL FEDERAL R&D AND BASIC RESEARCH EXPENDITURES
1960 — 1988
(1987 CONSTANT DOLLARS)



SOURCE: DIVISION OF SCIENCE RESOURCES STUDIES.

Figure - 5

FEDERAL OBLIGATIONS FOR R&D AT UNIVERSITIES AND COLLEGES AS A PERCENTAGE OF ALL FEDERAL R&D



SOURCE: DIVISION OF SCIENCE RESOURCES STUDIES.

Figure - 6

Mr. WALGREN. We will turn to Dr. Powell.

STATEMENT OF DR. JAMES L. POWELL, MEMBER, NATIONAL SCIENCE BOARD

Dr. POWELL. Thank you, Mr. Walgren, and I would like to thank Mr. Wolpe, a "Reedie," for his warm introduction. And I certainly enjoyed meeting him and having breakfast with him this morning. I will do my best to make sure that his alma mater maintains its traditions.

I do not have a prepared statement this morning. I would merely like to share a few observations with you. First, a little bit of personal history. I first appeared before this committee in 1975, when Mr. Mosher was sitting up there, a giant of a man who has left some very big shoes to be filled in this area. Mr. Walgren has certainly filled them admirably, but I think all of us interested in science education owe a real debt of gratitude to Mr. Mosher.

The next time I appeared was in the early 1980s, at a time when Director Bloch was speaking of, when the science education budget was headed for zero, and at a rather rapid pace. As we know, things look much, much better today.

In those days, only seven or eight years ago, we were not so aware as we are today of the impending crisis in science education. Today, one can hardly pick up a national newspaper without being reminded of it again. Just this week there was a conference put on by the American Medical Association where Dr. Shakhashiri and I both spoke.

The AAAS has come out with an exciting new program. The scientific societies are getting involved. Of course, NSF has been concerned about this for years and is, as I see it, really at the center of this most important effort.

As Mr. Boehlert suggested, it is not necessary to remind this committee of all the depressing statistics that we read about. I would just like to mention two that make a particular impression on me.

One is that, as we know, science and engineering expertise and education is important, crucial, to competitiveness today. We know that the Japanese and, increasingly, the Koreans have been taking our ideas and doing better with them than we have been able to do.

Now we also know that Japanese and Korean children are outscoring our children on these international science and mathematics tests, and I am worrying that we are going to get to a point where they will have their own ideas better than our ideas. Then where will we be? That is a concern.

Another concern is, in a way, I think, an advantage, and again, Director Bloch spoke about this. We have a great increase coming in our work force in women and minorities. We have an untapped pool. You can think of it as the glass half full, I think, as well as half empty. If we could find a way to bring more women and more minorities into science and into engineering, we would be able to recognize a considerable benefit that we have over the countries I was just mentioning, where we are decades ahead in opportunities for women and where minorities are not even present in most cases.

These kinds of concerns are what have led the Science Foundation and the education and human resources portion of the budget to grow the most of any of the three areas that the director mentioned, by 22 percent in the budget we are talking about. This increase involves all levels, from elementary through graduate.

I was on the Neal Committee,[4] which focused on undergraduate education and how the country was doing. The fact that that committee existed reflected the concern of the director and of the National Science Board with undergraduate education, and the recognition that something was wrong and we needed to take a good look at it.

There was a recognition that, at the undergraduate level, the people who are not going to be scientists but are going to be college graduates take their last science course—that is, their last chance in a formal way to receive science education—and it is also, in a way, the first opportunity for people who are going to become scientists to take a serious, high-level rigorous course in science.

So, at the undergraduate level, you are really seeing an opportunity to educate citizens and also to get our future scientists and technologists started out on the right track. So it is quite critical.

That is the reason the Neal Committee was formed. It found, as you know, some serious problems in all areas: quality of teaching, quality of the curriculum, quality of equipment. And here, three years later, the Science Foundation has programs in science and engineering education in each of those areas funded at what I regard as a good level. It could always be more, but it is adequate, I think, and far better than it was just a few years ago.

The proportions are roughly those that were recommended in the Neal Committee report. I think the overall level is reasonable, given that for one year we had very little overall growth in the Science Foundation budget.

Let me mention a specific point that has come up before this morning, and that is the relationship between education activities conducted in that directorate and ones conducted in the research directorates. I can assure you that the Education and Human Resources Committee[5] discusses this subject, this balance, several times a year, and we recognize that, in an ideal sense, research is teaching. It is certainly teaching the researchers, but we think it also is teaching the students who are working in the laboratories.

This is most clear, I think, at the graduate level; no one would argue with it there. It may not be always understood that research is also a form of teaching at the undergraduate institutions.

One statistic from Mr. Wolpe's institution: Over the last decade or so, there have been several hundred papers written by faculty members at Reed College, and one-third of those papers have had student co-authors. One-third of the papers written by the faculty have had student co-authors, undergraduate co-authors, and I think that makes that point quite vividly. The statistic may be different but the general point is the same, I think, at undergraduate institutions across the country.

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[4] National Science Board Committee on Undergraduate Science, Mathematics and Engineering Education.

[5] A committee of the National Science Board.

There is always a question of the extent to which we want science and engineering education activities in that directorate, to what extent we want them in the research directorates. On the one hand, we do not want to "ghettoize" that whole activity by putting it in one directorate. If you believe that research is teaching, then you must want the research directorates to have some responsibility.

So it really comes down, it seems to me, to a matter of balance. I personally think that it is reasonable to, in effect, farm out some of the science education activities into the research directorates, as we are now doing. Though, given the pressures that are on the research directorates, I believe that we need to have a monitoring device to make sure that due attention is being paid to education, and we have such a device in the form of a committee in the Foundation.

I thought I might close by bringing up and ending with a new subject, in case the committee has some interest in the progress we have been making toward establishing the Office of Inspector General of the National Science Foundation. Could I just make a few remarks about that?

We are at least on track if not really, I think, somewhat ahead of schedule. We will certainly meet the statutory date next month. In fact, it would not surprise me if we have an inspector general appointed sometime next week.

We have already transferred the functions of the Office of Audit and Oversight of the Foundation into the Office of Inspector General, and we appointed the head of that office acting inspector general.

This whole area has already been functioning well at the Science Foundation. We have had an Office of Audit and Oversight for several years, so it is not something new.

The Board will be the supervisory agent for the inspector general. The chair of the Audit and Oversight Committee, which happens to be me right now, will be, in effect, the supervisor of the inspector general. The director will have day-to-day supervision, since people on the Science Board are obviously not there on a day-to-day basis.

We have some outstanding candidates for the job. I believe that our attitude on the Board and at the Foundation is that we see this as an opportunity to further sharpen an already very sharp organization.

Thank you, Mr. Walgren.

Mr. WALGREN. Thank you, Dr. Powell.

Dr. Moore, would you like to comment at this point?

STATEMENT OF DR. JOHN MOORE, DEPUTY DIRECTOR, NSF

Dr. MOORE. Thank you, Mr. Chairman.

I really have no lengthy prepared statement, but perhaps I could make a remark.

Dr. Powell referred to the question of balance with respect to the undergraduate programs. I just wanted to broaden that a little bit to speak about the education and human resources activities that we are undertaking.

Our general strategy is to try to develop a balanced approach to all of the objectives that we see in that arena, and that means balancing our programs along the educational pipeline, balancing them with respect to certain objectives—for example, broadening participation in science and engineering—and, in general, trying to apportion our resources within that particular theme in the most effective way possible.

We also, I want to say, have to achieve the balance between the educational and human resources thrusts in general and the other objectives, the other responsibilities, that the Foundation has. This committee is very familiar with those other responsibilities that the Foundation has.

That balance is obtained, or we at least seek to obtain that balance, through the process of priority setting that the director described a few minutes ago and that the Board and the staff and a lot of outside advisory groups participate in.

I just wanted to focus for a second on this general problem of balance and how it relates to priority setting.

Mr. WALGREN. All right.

Well, thank you very much for those statements, and I can certainly appreciate the need for balance and the difficulties within the administration and that you are coming up with a proposal for the amount of spending that you would support.

In the Congress, of course, we have some separated functions, and it seems important to me, when we talk about an authorization—and Members take different approaches to this—but when I look at my own personal responsibility, I would like to not see me and other authorizing Members standing in the way of what should be.

We have budget committees and appropriations committees, and they are particularly focused, because of the range of their jurisdiction, on balancing. But an authorizing committee is focused quite solely just on a relatively finite area. Like the jurist who said that it was important to remember that it was a Constitution they were interpreting, so I like to think that we ought to remember that it is an authorization that we are trying to develop in our committee, and I would argue very strongly that our committee should develop that authorization in a way that we are not standing and preventing things that should be able to happen from happening.

Consequently, when I think of science education, in particular, I would hope to see us authorizing what should be able to happen, and other parts in the system will have the responsibility to actually limit the dollars that might go into that range. But our role would be to point to the number that should be, so that we do not prevent something from happening that should happen.

Along that line, I wanted to ask particularly about in-service training for teachers. The National Science Board in 1983 had a report, "Educating America for the Twenty-First Century," and they recommended particularly for in-service training institutes for teachers $350 million a year.

Now, the total this year in the Science and Engineering Education Directorate, you are recommending $190 million of total effort, curriculum development and everything, when the Science Board, now eight years ago, recommended $350 million in in-service training alone. How much are we spending on in-service training now?

Mr. **Bloch**. Let me give you the answer to that question, but then I would like to make some other comments.

What we are asking for in 1990 is about $46 million for in-service training. Let me make a comment on that. You should also look at the approach that we are taking. The teachers, themselves, that we are bringing into these activities are then utilized to form a network with other teachers which have not had that experience, for whatever reason.

So I think there is a secondary kind of fallout from it, and I think that is true about many of our programs, not only in the education area but certainly in the education area, that we are trying to be a catalyst for something else to happen and not just the end-all of a particular activity.

Especially in an area like this where the responsibility for education—and pre-college education, in particular—is diffused in the country, in the localities, in the States, as well as in the Federal Government, I think the catalytic role of the Foundation is a very important one because under no circumstances can we do the total job, whatever that total job really means.

That is the first point I wanted to make in direct answer to your question. But I would like to make a more general——

Mr. **Walgren**. Well, perhaps you might—just one thought and then—well, if you would like to make a general comment, I don't mean to interrupt.

Mr. **Bloch**. Well, go ahead.

Mr. **Walgren**. What I would like to ask for is help at understanding what the total job really is because I think we should be enabling the society to protect itself and to act in its best national interest. I admit that the actual spending levels will be lower, but at some point in this committee process, I want us to ask ourselves what should the authority of the government to spend in this area be. So when you say it is not the total job, how do we decide what the total should be, which I am sure, at some point in your process, you start with and then try to measure back and balance back?

Mr. **Bloch**. What I tried to say was essentially that in order to address that issue, like many other issues, where the responsibility is diffuse and where it belongs to the localities and where it belongs to the Federal Government and to the States, I think we have to understand the totality of that particular effort, the State effort and the locality effort, so that we can measure how far we should go or how far we have gone.

What I meant to say was, we had better have the total job in front of us, and that is more than just what the Federal Government can do or should do.

Mr. **Walgren**. Maybe we can come back to what the total job of the Federal Government ought to be. As a footnote, I am struck by the fact that, as a measure of effort, we made a much greater specific effort in this area in the past. In 1967 we were, in that particular directorate, spending something in the range of 300 million or so present dollars—measured in terms of present effort, and of course, this year we are not.

But we will come back to that, and I want to turn to other Members. We have a lot of interest in this subject and a lot of people who would like to raise areas with you. I will bite my tongue and hope others will stay within seven-plus minutes or so, and then we will come back for another round if that will be the will of the committee.

Let me turn to the gentleman from New York, who I thought was my friend, too, and then I decided I had better get a dog. [Laughter.]

We got a standard poodle, by the way, which is very large. It fills in where Sherry falls short. [Laughter.]

Mr. BOEHLERT. Mr. Bloch knows that I am indeed his friend, and my comments perhaps should have been more directly geared to OMB. But I hope you are not offended that I suggest you be the science czar. I think it would be a wise move on the part of the President.

Mr. BLOCH. That is what I meant about friendship. [Laughter.]

Mr. BOEHLERT. Mr. Bloch, let's look at supercomputers for a minute. That is an area in which I have a particular interest and have had for a long time.

The Science Board is going to vote on the future of the supercomputer centers in May. Is it a question of continuing the centers, or is it one of—which ones we will upgrade?

Mr. BLOCH. Well, the review that you mentioned that the National Science Board will have in May is essentially a review of the performance of the supercomputer centers that have been now in existence for over three years.

With it goes obviously the question of where should these centers go. Should they continue the way they are? Should they be upgraded, as you mentioned? Should they be discontinued?

I think it is very important, in the center activities—and the supercomputer centers are a little bit different than the other centers, I must say, because they provide a service to the rest of the scientific community, not just doing research within their own four walls, so they are a little bit different—but, nevertheless, it is very important that we keep in front of us at all times the performance of these centers, and that is the first order of business.

The second order of business, all centers have been asked to submit their proposal of how they see their future, what they would like to do, and so forth, and we have taken these proposals, obviously, very seriously, and they will be discussed with the Board. We have a set of recommendations that we are preparing—are in the process of preparing, that we are putting in front of the Board, and the Board has to rule on that.

Mr. BOEHLERT. How many will get upgrades in the fiscal year 1990 budget?

Mr. BLOCH. Pardon?

Mr. BOEHLERT. How many will get upgrades in the fiscal year——

Mr. BLOCH. In the fiscal year 1989 budget?

Mr. BOEHLERT. No, the 1990 budget.

Mr. BLOCH. Oh, the fiscal year 1990 budget. Well, that depends, obviously. We have about $20 million allocated for upgrade, roughly speaking, and how far that will go depends what the upgrade involves. It will not be enough money to upgrade all of them to the latest level; that is clear. So the upgrade question is in front of us.

Obviously, the proposals which these five supercomputer centers submitted exceed the dollars that we have in our budget, which is always the case.

Mr. BOEHLERT. I am trying to figure out, would you go ahead with one or two and then the others eventually?

Mr. BLOCH. Well, maybe three.

Mr. BOEHLERT. And what about the other two?

Mr. BLOCH. Well, you cannot do everything at once.

Mr. BOEHLERT. I understand that, but——

Mr. BLOCH. We will look again——

Mr. BOEHLERT. This is not the beginning of the end for the other two, is it?

Mr. BLOCH. Definitely, the centers that survive, that will exist in the future, will need to be upgraded. We cannot let these centers fall back to a status quo that exists today, because the technology is moving on, has moved on, continues to move on. The requirements on the centers are increasing. By the way, the dependence on the centers is increasing. Once you are hooked on peanuts, you cannot let loose, and that is the same with supercomputing or computing in general. [Laughter.]

So we know that, and we are dedicated to make that happen. But, like in many other areas, and you mentioned a few before, we would like to do more, but within the present resources, within the balance that we have to bring to everything we are doing, that is about what we thought we could afford.

Mr. BOEHLERT. Let me just switch areas for a minute, if I may.

Mr. Bloch, you are a member of a number of interagency groups that are reviewing U.S. policy in areas like High-Definition Television. What steps do you think the U.S. Government should be taking in these areas? I mean, should we be funding civilian consortia, for example?

Mr. BLOCH. Well, yes, I am a member of a number of these committees, some of them put in place by the Administration, some of them put in place by Congress. Let me comment in a generic way first.

These are all different problems. I am on a committee for semiconductors. Semiconductors are a different problem from HDTV, very clearly. Therefore, there is not one solution, and you have to look at each one.

In the semiconductor area, the Government funded through Defense last year SEMATECH to the tune of about $200 million, about an equal amount coming out of industry. Probably, in my opinion, that was the right thing to do for that area.

HDTV is in a little bit of a different kind of situation. There the question is, the next round of consumer products will be something HDTV, no doubt about it, and we are out of the electronic consumer market completely. We are not producing it. We are putting labels on boxes that somebody else produces and then selling it in the country. And here is our last chance for a long time, not forever but for a long time, to gain a foothold in this new area.

It requires some technology, but technology is not the most important ingredient. It requires manufacturing know-how capabilities, marketing, and so forth. I don't know what the answer is, to be very honest. But I think, first of all, the companies themselves, industry itself, has to be the main actor in that activity. You cannot design an HDTV set in Congress; it doesn't work.

Mr. MINETA. Would my colleague yield on that point?

Mr. BOEHLERT. I would be glad to, sure.

Mr. MINETA. But aren't we falling into the same trap as we are maybe with SEMATECH, because we turned to the Department of Defense for funding of SEMATECH? Aren't we falling into the same trap now with HDTV, with DARPA now beginning, at least for the time being, a very major part of the funding for HDTV?

It seems to me that we are going down the wrong track, that that really ought to be a civil pursuit, and it ought to be, really, in terms—and going back to these on R&D, I think the problem that we are facing is that we are putting too much money into basic sciences that others take advantage of, and we are not putting enough money into R&D in two areas. One is manufacturing, and the second part is in terms of commercialization of product.

We do a good job on basic sciences, but it seems to me—and I am not saying this to fault you, Mr. Bloch, really, believe me—the problem is that, in the case of HDTV now, it seems to me that maybe what we have to do is sort of draw a curtain around it so that we let our own industries get a toehold before foreign competitors really move out of—ahead of us and then we really lose a very significant market of a consumer product in the future.

Mr. BLOCH. Well, Mr. Mineta, I agree with 50 percent of what you are saying, but the other 50 percent I have got to take issue with. But let me stay with the agreement first.

Mr. MINETA. Mr. Bloch, could I ask which 50 percent? [Laughter.]

Mr. BLOCH. It will become very apparent in one minute.

Your first point was, why do we go to Defense to support SEMATECH or support HDTV like DARPA is doing right now? I only have one answer: that is where the money is. And that is a fact.

By the way, there is a rationale for Defense supporting SEMATECH, because they are depending on that technology more probably than on many of the other technologies. So they have a stake in it.

I would be also more satisfied if that were administered by a civil organization instead of a defense organization to make sure that the focus is on commercial fallout and commercial development. So I agree with you on that part.

But, rather than not doing anything, I like the support that I see coming out of Defense and DARPA for these two activities.

Mr. MINETA. But the problem with the rationale of saying, "well, Defense has the money to fund these things," is that then we start giving away things to be funded by Defense. We do not then get—because of compartmentalization and security requirements—we do not get technology transfer into the civil sector. It just seems to me that we keep doing that.

Even in another program as it is related to the whole science and math education, according to your testimony, you are supporting a program that is over at the Department of Education. Again, it seems to me that that ought to be in the bailiwick of the National Science Foundation instead of being given away.

Well, I appreciate the time yielded.

Mr. WALGREN. The gentleman's time has expired.

Mr. MINETA. Thank you very much.

Mr. WALGREN. The Chair recognizes the gentleman from Michigan, Mr. Wolpe.

Mr. WOLPE. Thank you.

Mr. BLOCH. Mr. Chairman, I never had a chance of saying what I disagree with. [Laughter.]

But it has to do with basic research. I agree with you; we should put more money into the applied research area. But let's not shut one off because we have a problem in the other area, and then create another new problem for us. Let's look at the balance between the two, and try to do both of these things. That was my point.

Mr. WALGREN. Mr. Wolpe?

Mr. WOLPE. Thank you very much, Mr. Chairman.

I would like to follow up on the question that Mr. Mineta was raising. I happen to concur wholeheartedly with the basic point.

Back in 1980, as I recall the numbers, of every dollar that was being invested in R&D in this country, 50 cents was going to the Pentagon and 50 cents was going into civilian R&D. The numbers that I saw about a year ago—and I am not sure what they are today—it was 72 cents of R&D that was Pentagon-based and no more than 28 cents was being targeted for civilian research.

Are those numbers still basically applicable?

Mr. BLOCH. No, not quite. Your 72 cents today, if you look at the 1990 budget, is about 65 cents.

Mr. WOLPE. If that budget is approved in the way it has been framed?

Mr. BLOCH. Right, but it is more than it was in the time period that you indicated, where it was more 50-50.

By the way, I don't believe that necessarily tells the story. There is another part to it that makes a more important argument. If you look within whatever the defense R&D budget is, if you look at the distribution of that to basic research and education—you define education for a minute—you will find that that part of the defense budget has decreased on a percentage basis, spending less than $1 billion today on basic research.

Mr. WOLPE. The argument has always been made that there are always these spinoffs from the defense research, and therefore one ought not be concerned about the source of allocation.

Mr. BLOCH. Well, the spinoff is also in the other direction.

Mr. WOLPE. But I recall that last year—and you did a hearing, Mr. Chairman—we received testimony from the industrial sector that just laid out in very graphic terms the lack of spinoff and the extraordinarily weaker kind of return on R&D investment that is the product of that kind of disproportionate emphasis on the Pentagon.

Then you raised a moment ago, as you got into this question of don't cut basic but just simply add onto what is needed in the other areas, that obviously raises the issue of priorities.

One of the biggest concerns, I think, that the scientific community nationally is beginning to express—and I think we in the Congress have—is the competition for scarce dollars as it relates to the big-ticket items such as the supercollider venture, and the impact that something like that might have over the next several years on basic R&D.

The question that I would like to hear some discussion of from you is how would you, sitting here in the Congress, approach that question? I mean, what are the proper criteria to employ as we try to assess the relative—assuming we have got to make some choices here—the relative merits of something like—let's take the supercollider specifically in contrast to other areas of funding?

Well, I am absolutely delighted by the kinds of increases that have occurred in your budget the last couple of years and that are now projected into the future. I am also much less sanguine that those increases are going to be sustainable. I think that the possibility of sequestration is a real one this year, or next year, if we do not get a different kind of approach to budgeting from the Administration. I think that is a very real possibility. And not only would you not have any of the projected increases, if that were to occur; you would actually have somewhere in the neighborhood this year of a nine percent reduction across the board in your program activity.

That is the budgetary reality that we are dealing with. I think there are going to be some hard choices to be made, and I am searching for a way in which to make them rationally. What are the criteria that we ought to be applying, the questions we ought to be asking in making that determination?

Mr. Bloch. Well, I need to say, first of all, that the administration supports the SSC. I think that is a wise decision because we need continuation in that disciplinary area in terms of the equipment and instrumentation that moves the field forward.

Mr. Wolpe. Let me say that, conceptually, I have also embraced that. I think I have never heard a critical, negative remark about the wisdom of doing that, but my question is a different one. What if you have got to choose between that——

Mr. Bloch. I am getting to that question. The question now becomes one of priorities, and I must say I have been very heartened by the fact that the same administration, and the previous administration, also, have put the Science Foundation's doubling budget on the table together with the SSC. And I interpreted that that has a higher priority. For me, it certainly has a higher priority.

I think Congress has to ask itself the question, out of the limited resources that we have—we don't have enough resources to pay for all of it—which are the most important aspects? In my opinion, the most important aspects are the infrastructure, addressing the infrastructure, and that means people, education, basic research. If you don't have that, then these big programs are not very useful.

We have got to generate the people that can use these tools. We have to have the underlying basic understanding and basic knowledge that are required to operate these tools and get the benefits from them.

So, to me, the National Science Foundation doubling has priority over everything else; and, if that means stretching out the schedules on the other programs, I will say, so be it.

Mr. Wolpe. That is a useful response. It does lead into one other question as it relates to the priorities within the NSF's own budget, and that is, the increase for pre-college programs is only eight percent in the year in which the total NSF budget is increasing by 14 percent. The total science education activity is increasing by some 28 percent.

We receive a lot of testimony that affirms that there is a major crisis in science and math education in the primary and secondary schools. I will not read through the litany of those reports. But I am just wondering, how would one rationalize that small an increase in an area that I think is sort of the starting point for restoring our science base in this country?

Mr. BLOCH. Well, I am glad you are bringing this up. That was really my general remark which I never have been able to make before when the chairman talked about it.

It almost sounds that we are on the defensive here on this very important area, and I wonder why because, if you look at the record, with your help and with the Appropriations Committee's help, we have increased the budget of the Science and Engineering Education Directorate in which these pre-college programs reside significantly over the last few years. For instance, since 1985 it has doubled; that budget has doubled.

The area that you are talking about—since 1988 we have had increases in the teacher program of about 50 percent and in the materials development program of about 30 percent. What has happened this year, and why you only see a 10[6] percent increase versus a 14 percent increase for that whole directorate—for the Foundation, is the fact that at the same time the Department of Education has gotten a major allocation of dollars and program requests from the Administration. Many of these programs intersect essentially the ones that we have. So I think we should look really together at both the Department of Education allocation, as well as ours to make a judgment where we are today.

Mr. WOLPE. Well, I appreciate that, but I also think there has been a greatly overstated characterization of the Administration's education request this year, which is $100 million, as I understand it, below President Reagan's outgoing budget for education. And within that total, it calls for 40 to 50 percent reductions in a whole series of segments of that education budget. So I am not so sure that that is cause for great optimism.

Mr. BLOCH. But it shows, also, a $400 million increase in some of the programs that intersect with ours. By the way, we want to take advantage of those. We have been with Secretary Cavazos a couple of times now, both Dr. Moore, Dr. Shakhashiri, and myself. And we are determined to work with them to make these programs jointly function so that we know that we are covering the right bases and there is no unnecessary kind of overlap between the two, because some programs lean directly on the programs that we have.

Mr. WALGREN. The gentleman's time has expired.

The gentleman from California, Mr. Brown.

Mr. BROWN. Thank you, Mr. Chairman.

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[6] The FY 1990 budget request for the NSF Science and Engineering Education Directorate is 11 percent above the FY 1989 appropriation and the total NSF FY 1990 budget request is 14 percent above the FY 1989 appropriation.

Dr. Bloch, I should begin by indicating my own feeling of satisfaction with the general course which the Foundation is taking and with your own leadership. I think it has been admirable. But, nevertheless, no product of the political process is perfect; and, as you have heard here, we have marginal criticisms in a number of areas.

The criterion of balance which has been enunciated here is useful, but one has to keep in mind that balance is in the eye of the beholder. Going back before 1980, the amount devoted to education in the Foundation's budget was far larger than it is today, and yet it was the feeling of some people, at least in the previous Administration, that that was an improper balance and that education was not a proper role for the Federal Government, which led to that fast decrease that occurred at that time.

Now we are restoring balance. We are up to half of what we were doing 15 years ago. I am not being critical about that. I think we have a better program today. I was disappointed that what we spent back in the sixties and the seventies did not produce a permanent, long-term improvement in the teaching of science and engineering and technology. And my fundamental question is, why?

You have focused a program in this area now which is modest enough in terms of dollars, but you say that it is based on encouraging partnerships and sharing in the responsibility for these improvements, which works in many areas. It ought to work in education.

One of the most impressive pieces of testimony we heard was from a professor at University of California at San Diego, I think, who testified on what they were doing, what he was doing, on an NSF grant to improve education in the local schools there in a partnership arrangement. I was deeply touched by what he was doing.

But I want to raise this question, and I don't want to make too many speeches in doing it. Part of the problem is that we do not encourage a concept of the importance of science and technology in our teacher training institutions. We discourage in many subtle ways. One is that we do not provide any encouragement to research activities per se in these teacher training or multipurpose universities. We think most of the research money ought to go to the great centers of excellence, the research universities.

Do you know what this does? It creates very good science, but it makes the other people in the other universities feel that they are second-class citizens. And they have many very good people who might not produce world-class research but need to be inspired to conduct whatever research because that is a part of the learning process.

We need to focus on that; and, if we do not, no matter how many dollars we spend, we probably will not be able to create the climate which encourages students at the elementary and secondary level to get into science, which encourages teachers to become good science teachers, if we engage in subtle forms of discriminating against them through the institutional structure.

Would you comment on that, so that I can stop? [Laughter.]

Mr. Bloch. I would be glad to comment on a number of things which you mentioned. Let me start with the last one.

I agree with you that teachers need to be encouraged to work and have some experiences in doing research in the sciences and the mathematical areas. I think we are doing that in a direct as well as an indirect way by some of the programs that we have put in place of undergraduate activities.

We have a program called Research Experience for Undergraduate Students, a relatively new program. It is now in its second year. I think that could touch a lot of the people that you are talking about, a lot of the students that later on become teachers. By the way, these programs are open for four-year colleges as well. In fact, many of the four-year colleges participate in the program.

We focused on the question of undergraduate research. We have a program primarily aimed at four-year colleges to do undergraduate research in the four-year colleges. That point was driven home very hard a few years ago by the group of colleges that were called the Oberlin group, and Jim Powell was a member of that. We focused on their requirements, and I think we have acted accordingly.

In the end, you might say that we are not spending enough money on it, and that is true about a lot of things. But at least we have put that plan in place, and we have activities in place, and I think they are being used. And I think today there is a different kind of relationship that the Foundation has with four-year colleges as well as with undergraduate research than what existed in the past.

I want to comment further on your long-term improvement and the lack thereof in the sixties, and that is of great concern. These on-again, off-again situations, I think, are deadly. They give the wrong signals, and it takes a long time to recover from them. I hope that by having a more cautious approach that we are pursuing today in the education program, by the fact that we are linking them to the research universities—and you gave one example; we can give you other examples—that we are linking them to industry where we can, hopefully—will provide a more stable kind of platform for the future. And it will not be this on-again, off-again situation.

For every program that we are putting in place, we are putting some kind of measurement program in place so that we know after a few years—you will not know overnight, but after a few years—what these programs can accomplish, what they have accomplished, and through that method, hopefully, get more support for these programs into place.

But I would caution that we do not go overboard and dump money in there and then indiscriminately spend it, but that we are selective on the programs that we spend.

Just one word of correction. It is not quite as bad as people make it out to be. In the 1960s, we had about $500 million constant 1988 [7] dollars in the various activities that had to do with education. By the way, a number of these programs were graduate programs, postdoctoral programs, and so forth.

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[7] NSF has indicated that this should be "1989 dollars."

If you compare that to today, we have about $500 million in these programs. Today they are more distributed. Many of them are in the research areas. And, by the way, there is a good reason for that. It is very important for what I just said a minute ago and what you indicated before, Mr. Brown, that the research directorates have a responsibility for the education of their researchers—that is extremely important—and not look at education as something which is a corner of the Foundation and they have nothing to do with it. That is why we are distributing some of these programs.

But the difference between the two is not that great. In some areas, the difference is more than in other areas. But these $500 million in the sixties included many of the programs that exist today, including an undergraduate component which fell by the wayside, also, by the way, in the eighties.

Mr. **Walgren**. The gentleman's time has expired.

The Chair would recognize the gentleman from New Jersey and ask our colleagues to join with me in extending this courtesy to him. He has a time commitment and got here bright and early to get at something, and he wants to get to it.

Mr. **Torricelli**. Thank you, Mr. Chairman.

I will be brief, but I appreciate the opportunity.

I have a specific question to ask Mr. Bloch. Before I do, I would just like to identify myself, if I could, with Mr. Mineta's remarks. I could not agree with him more strongly. And if this morning is to serve some purpose to you and your work in understanding our sentiments about the struggle to have America begin in the fight of the future electronics industry, I hope you will leave here today with an understanding of how much he spoke for many of us.

Some day, frankly, Mr. Bloch, a book will be written about how America perhaps—I hope not—lost the fight for high-definition television and hence, perhaps, the future of the electronics industry. And your comment that television will not be designed in the U.S. Congress will be a fitting title for one of the chapters. [Laughter.]

Because I can assure you that the hands of the Diet and the Bundestag and apparently now the Central Committee are going to be all over their products. The age when an individual company could invest funds of that scale, with that level of competition, with that level of risk, without some national plan of coordination or shared or subsidized resources, in my judgment, is over.

I think Mr. Mineta spoke to reality, and I hope that his comments remain with you when you leave today.

I wanted to ask more specifically a question relating to the authorization of last year. There was in that authorization a very specific provision with regard to intentions to construct and purchase an icebreaker for scientific research. This committee and the Congress as a whole made clear in that authorization its views on that procurement: that it be from a domestic yard, unless a certain dramatic distinction was made in the bid prices.

There are some who believe that it is the intention of the Foundation today to circumvent that restriction by entering into a series of leases during the construction period, which is permitted, but then perhaps beyond it so as to avoid the intentions of this committee.

I wanted to make clear my view, as the author of that amendment, that to do so would clearly violate the intention of the committee and the Congress as a whole. And if you would, I would ask you to respond to the procurement process today, your intentions with regard to the icebreaker, and to please set my fears at ease with regard to any efforts to circumvent it.

Mr. BLOCH. I don't know where you got the impression that we are trying to circumvent Congress' will in this particular area, because we are in the middle of the process of doing exactly what Congress said we should be doing.

We issued an RFP on February 6, 1989. The proposals are due in May. We have had interest, a large interest, in this RFP. There are about 75 potential bidders. I don't expect 75 bidders, by the way, but just by the number of bidders, we probably will get a large number of them. What these bids will show I do not know.

Mr. TORRICELLI. Do you intend to enter into a rental agreement in the interim?

Mr. BLOCH. In the interim, we have to do something, yes. And I would hope, by the way, that out of this bidding process will come some indication of what that is, because we are not only asking, if I am correct, for purchase prices, but we are also asking for rental prices.

Mr. TORRICELLI. But it is your intention, and you understand the intention of this Congress to be, that you enter into, as you are doing, and accept a proposal for construction, have a rental during the construction period, but a rental agreement is not a substitute for the construction? That was our intention, and I simply want to clarify whether it is yours at the moment.

Mr. BLOCH. Well, maybe we are quibbling about words, but let me say one thing. I have seen many capital acquisition structures, and we have a few right now in the supercomputer area, that was talked about before, where we have entered into a long-term rental agreement in preference over a purchase agreement. By the way, from the manufacturer's viewpoint, that was acceptable, and I think you should leave it up to the process to make that decision in the end.

Mr. TORRICELLI. Mr. Bloch, I am pleased to leave it up to the process. My purpose in raising this is, there are those of us who are on this committee because we believe in science but also strongly believe that the funds and the drive that make our scientific strength possible are because of an active industrial base, and we felt deeply offended at the notion that the United States Government was going to go offshore for ship construction. That is prohibited for all of our agencies of defense; it should not be allowed in other parts of our civilian government agencies as well.

We designed a structure to clearly steer in that direction, and I simply wanted to raise it today in the hope that you would recognize that spirit and our intentions in the amendment. It appears to me that you do, and I appreciate your answers today.

Mr. WALGREN. The gentleman's time has expired.

Mr. BLOCH. If I just could say one more word about that, look, we are with you, and we are seeing our mission not only to support research but also to support the economic competitiveness of the country. And we have in the past shown that. If you look at our supercomputer centers, for instance, the same conversation I had with you, we had with Congress a couple of years ago on that when it came to the fact that foreign manufacturers were trying to enter into the bidding contest. If you look at our supercomputer centers today, it is all made in America.

Mr. Torricelli. Thank you.

Mr. Walgren. I thank the gentleman.

The gentleman from Colorado, Mr. Skaggs.

Mr. Skaggs. Thank you, Mr. Chairman.

Good morning, Mr. Bloch. I have a couple of questions I would like to pursue with you.

My office received some budgeting data that I believe originated at NSF concerning the resources going into global change research, and they give some conflicting impressions.

On the one hand, the proposed increase in your budget from about $39 million to $53.5 million for next year is obviously significant and would account for over a quarter of the government's overall work in the area.

On the other hand, other agencies such as USGS and NOAA are making significantly greater proportional increases in their budgets, and I am just wondering if you could comment on that and give us an idea of the relative importance that NSF will be giving to global change research over the long haul.

Mr. Bloch. Your numbers that you are citing on the global change activity itself are correct. We are going from $39 million to $53 million. By the way, that represents over 25 percent of the total that the government spends on this coordinated activity, coordinated across the various departments.

You can call that focused research on the global geosciences. But you should also know that there are other activities in the Foundation, not only in the Geosciences Directorate but also in the Biological Sciences Directorate, that essentially provide the underpinnings to many of these activities.

If you look at our total budget, the global change and the global geosciences together, it is about $173 million in total, which is not an insignificant portion of the total research budget of the Foundation. You should look at us as a contributor to the particular global change program, but you should also look at us as providing the basic research in many of the other areas that are needed in order to move forward in a real sense in addressing this problem.

Mr. Skaggs. Thank you.

Last week, I guess, the committee received the report that you prepared pursuant to one of the comments in our report on the authorization bill last year on technology transfer. One option that was discussed in your report on potential for improving NSF's technology transfer activities was the idea of funding research into the technology transfer itself.

In the work I have tried to do in my home area to bring government laboratories and industry and universities together, I am finding that it is a difficult pathfinding exercise to figure out what really is involved in this.

I would like to encourage you—and perhaps, Mr. Chairman, we could pursue this further at another time—to look at that, and I would also ask your comments this morning as to whether this is something that we might nudge you forward on a bit.

Mr. BLOCH. I don't know if any nudging is necessary. It is obviously a subject that comes up time and time again. It is a difficult area because the best technology transfer is between people, if people work together, obviously. But there are other ways of doing it, and we are going to pursue that area in one form or another.

Also, as we gain more experience with some of the projects in the Foundation that are more geared to technology transfer, like the center projects, for instance, I think we are going to apply what we learn there to other projects in the Foundation. Let me assure that we have a focus on that issue. As you said yourself, it is a complex issue.

Mr. SKAGGS. Well, I would appreciate it if perhaps, for the record, you could supplement exactly how you do intend to pursue what is identified as option C in your report.

Mr. BLOCH. All right.

[The information follows:]

The report on technology transfer outlined many programs at the Foundation which seek to emphasize a relationship between industry and the university research community. From evaluations we know that 50% of SBIR projects entail university participation in some form. Industry/University Cooperative Research Centers represent another program which has been in operation at the Foundation for some time. Data from this program can also be evaluated to assess factors which best promote technology transfer from the university to industry.

It is our intent to systematically assess: (1) our experiences with these programs to obtain valuable information about the effectiveness of various technology transfer mechanisms in stimulating the movement of knowledge and technology between university-based research and the private sector; and (2) the degree to which these projects have stimulated industrial cooperation with university research or utilized the output from university research in the development of private sector products.

The Foundation is also considering the design of a study that would assess the U.S. science and technology information system. The flow of such information, an important aspect of technology transfer, is undergoing very rapid technological and organizational change and, thus, the study and analysis of this system is expected to contribute significantly to our understanding of technology transfer.

Mr. SKAGGS. Finally, I think we are all aware that the peer review process for evaluating grant proposals is a critical cross-cut process issue for the Foundation. I represent an area in which many of my constituents are at your mercy, if you will, in that process, and I am curious what appellate review there is for decisions coming out of the grant application peer review process—whether you find that that appellate review, such as it might be, is adequate; and, if not, what you might be doing in that area.

Mr. BLOCH. Dr. Moore should answer that question.

Dr. MOORE. Mr. Skaggs, there is a procedure that is set down in our regulations for appeal of decisions made under the merit review process. This is followed. We deal with perhaps, I would say, 25 or 30 appeals a year. I happen to be the last stop on that particular road, and I occasionally have to deal with one that is not resolved earlier in that particular process.

We do occasionally, not very frequently but occasionally, reverse a decision that is made in the peer review process. So it exists. If you would like, we can provide you with the details of exactly how that works.

Mr. SKAGGS. I would appreciate that.

[The information follows:]

Award of NSF assistance is discretionary. Nonetheless, it is the policy of the Foundation that an applicant whose proposal has been declined may receive an explanation and reconsideration.

A Principal Investigator (PI) whose proposal has been declined may obtain an explanation of the declination from the responsible Program Officer. If this explanation does not satisfy the PI that the proposal was fairly handled and reasonably evaluated, the PI may request reconsideration of the declination by the responsible Assistant Director. If the applicant institution is still not satisfied after reconsideration by the responsible Assistant Director, it may obtain further reconsideration by the Deputy Director of NSF. However, if a proposal has been declined after review by the National Science Board, only an explanation will be available.

Mr. SKAGGS. Thank you, Mr. Chairman.

Mr. WALGREN. Thank you.

The Chair recognizes the gentleman from Louisiana, Mr. Hayes.

Mr. HAYES. Thank you.

Earlier, Mr. Brown was speaking to some issues that I would like to parallel, first by thanking you for your recent visit to my alma mater, Tulane University, and later on going over to Louisiana State and Southern.

I was very interested in the EPSCOR award which you announced. It received certainly very favorable press. I played an instrumental role in that by not interfering with Mrs. Boggs. [Laughter.]

But what I would like to ask this morning as a companion, perhaps, to the earlier question was tell me a bit, if you would, about the long-range plans for EPSCOR and also the other similar NSF initiatives that you have announced and touched upon very briefly at other occasions.

Mr. BLOCH. Well, let me talk about EPSCOR first. As you know, that is a program of long standing in the Foundation. This is about our third group of States that we are looking at and that we are considering and have already awarded, Louisiana being the one that we have already awarded.

It is a program that requires the States themselves to do a lot of the work, as you know very well. They have to prepare their own plan. They have to contribute materially to the cost of the program, matching ours, essentially, and then make sure that they are following through over the grant period, which goes over years.

We have found one of five States that are now being looked at. We have a continuation of eight States that we are considering over three years, and we have around three or four States that have their initial awards this year. So it is a moving kind of process.

The point that was made in the past about it is, the original plan was really for three years—was it three or five years?

Dr. MOORE. Five.

Mr. BLOCH. Five years—I am sorry, I stand corrected—a period of five years, and then we were done with those States. The input that we got from the individual participants, as well as from Congress, was that that was too short a period of time and that we should continue working with these States after the five-year completion of the first round. We are looking at how we can do that best for future considerations.

So we are taking the project seriously. I think it has resulted in very fundamental and good changes in many of the States, not in all the States.

Mr. WALGREN. Thank you, Mr. Hayes.

The Chair recognizes the gentleman from North Carolina, Mr. Price.

Mr. PRICE. Thank you, Mr. Chairman.

Mr. Bloch, I would like to thank you for a very interesting, very articulate statement, very helpful statement about the evolving role of the National Science Foundation. I appreciate your comments about how the NSF is now tied more closely to national policy concerns in the way it operates; also the more active role you have assumed in instigating scientific efforts and instigating interaction with business and industry. It is a very helpful statement.

I would like to focus on the behavioral and social sciences in the time that I have, following up on a hearing that we had earlier this week. We heard from a distinguished panel of social scientists who provided many examples of the ways in which research in their fields has significantly benefited the public policy decision process.

The evidence would suggest that there are many research opportunities and that the research has in the past resulted in identifiable social payoffs.

Still, the NSF seems, in the overall scheme of things, to assign a relatively low priority to the behavioral and social sciences in its budget allocations. As you know, the social science budgets were cut significantly in the early 1980s and are only now reaching the level that they had in 1980 in current dollars, and that represents a 30 percent decline in constant dollars.

The fiscal year 1990 request, like all recent requests, proposes smaller increases, in the seven to ten percent range, in all components of the social science programs, smaller increases than the 14 percent average increase proposed for the National Science Foundation as a whole.

What is the reasoning behind these budget proposals?

Mr. BLOCH. Well, Mr. Price, whenever you listen to—and I do it probably every day and at least three or four times a week—if you listen to groups that come in, that represent a certain discipline, nobody has ever said that we allocated too much of a budget to them. So it does not surprise me that you hear the same comments out of the behavioral social science community.

Mr. PRICE. But you do not dispute the figures that I gave as accurate reflections——

Mr. BLOCH. Well, let me put it in perspective. I certainly do not dispute the figure that you gave where we are today. But you should know that, over the last five years, we have been rebuilding this particular area. You said very correctly that the area got somewhat decimated, not completely but somewhat decimated, in the early 1980s. We have reshaped the programs and we have rebuilt that area.

Let me give you just one interesting accounting. If you look at the increases since 1982 which the Foundation got in total and you look and plot against it the behavioral and social sciences areas, the behavioral and social sciences area got more of an increase in that time period than the National Science Foundation got in total.

There is no doubt in my mind, and there is no doubt in the record, that certain disciplines, certain areas, certain initiatives got more of an increase than the Foundation got. But the behavioral and social science area got, I will say, a 20 percent greater increase than the Foundation as a whole [8] starting from 1982 over the last seven or eight years.

You should realize—and, by the way, this is in a ratio basis, so the constant-dollar argument does not come into play. But let me just remind you that, except in the last three or four years, three years, since 1985, the National Science Foundation budget was a constant, in constant dollars, over about a 20-year kind of time period. And we are forgetting that.

Look, I believe very strongly that the behavioral and social sciences have a lot to offer, and they do a lot for all of us, and they are part of the science picture. So it is not discrimination at all, and I think they have been well treated. They have not been as well treated as they would like to be, and I understand that. And I hear the same complaint from other areas.

The other point I want to make, and it is a strong point that I make to everybody, the behavioral and social sciences community can not only look to NSF as its funder. There are also agencies in the Federal Government that have an interest in their research, in furthering their research, and they need also to be concerned, like many of the other disciplines are, with the contributions from the rest of the government. So you cannot just look at the National Science Foundation as the sole provider for this particular discipline, just like we do not do it for other disciplines.

Mr. PRICE. I know that is true; but, when you do look at those overall figures, they are not terribly encouraging. The behavioral and social science percentage of overall Federal research efforts has dropped over 15 years by something like a factor of half, from something like eight percent to four and a half percent.

Let me go back to your comment about the more assertive, the more active role that NSF is taking in marking directions for research. What do those priorities look like in the social and behavioral science area? What kinds of areas have you identified that you want to instigate and encourage?

Mr. BLOCH. As an example, I just was with a group that concerned itself with next year's programs for decision management research. I urged them very strongly that they align themselves with industry—they had some industry people on their panel—with industry in this particular effort, and get foundation funding and get matching funding from industry.

By the way, we are doing that in many other areas, and I do not think that is such an outrageous idea. By the way, I also think it would be a very successful attempt. So there is one example, and I think it is a very good example.

Let me just give you a number. We have in 1988, out of approximately a $1.5 billion or $1.6 billion research budget, we have had matching funding from industry and the States to the tune of about $300 million.

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[8] NSF pointed out that the comparison should be stated as "20 percent greater increase than the Foundation's research budget."

Mr. PRICE. How do priorities of that sort get communicated to the research community?

Mr. BLOCH. Well, in many ways. First of all, in the Engineering Research Centers, which is one of the main activities, it is in our solicitation. So the academic community has to go out to industry and get participation.

In the Presidential Young Investigator program, it is the individual researcher who has to make a connection with industry and get funding from industry before he can get additional funding from the Foundation. So many times it is in our solicitation.

Mr. WALGREN. The gentleman's time has expired; and, if we can stay with it, we are getting to the point where you will get another opportunity very quickly.

Mr. PRICE. Fine. Thank you, Mr. Chairman.

Mr. WALGREN. The gentleman from Missouri, Mr. Buechner.

Mr. BUECHNER. Thank you, Mr. Chairman, and I thank my colleague from California for yielding a little bit here.

Dr. Bloch, it is nice to see you, as always. I was honored to be able to go with a few other Members down to the Antarctic to visit our research facilities down there. I know you touched on it briefly in your opening remarks.

I would ask, perhaps, that you talk a little more in detail about it, primarily two things. Number one, what are we going to get out of this five-year plan with the significant increase that you have requested for the Antarctic?

And, number two, maybe to explain a little bit to the Members just what extra responsibilities the United States seems to have in the Antarctic. By that I mean emergency response, the fact that although there are many other countries down there, that many of them depend upon us for medical care of a more, I guess, sophisticated measure other than, say, paramedic treatment, so that some of the burden that we share goes beyond just taking care of United States interests, but is more of an international basis.

Thirdly, obviously, you are aware of the criticism of the Environmental Defense Fund. They think that the United States is a participant in the rape of Antarctica, I guess would be maybe a little bit of a dramatic phrase. But if you could kind of, with some specifics, tell us what the National Science Foundation, as the overseer of our Antarctic expeditions, what you are doing to ensure that not only are existing problems cleaned up, but that other problems are not going to occur.

Mr. BLOCH. Yes, I will be glad to talk about that. Let me make some general comments and then ask Dr. Wilkniss, who is in the audience, to step forward and give you a more detailed report. As you know, Dr. Wilkniss is in charge, among other things, of the Antarctic program.

But let me make a general comment. You have seen the conditions in Antarctica. It is a very difficult environment, at best. We are operating, and have been operating over 30 years, the major installations in Antarctica of any country. Over the 30 years, a lot of things have changed. Attitudes have changed, obviously. Regulations have changed. Legal requirements have changed, as well as the technology has changed that allows us to do things differently today than they were done 30 years. And that is true in this country, and it is certainly true in Antarctica, also.

So I think the problem that we have in Antarctica is that we have to essentially come to grips with our past. And we have to clean up what is there, first of all, and then make sure that what we are doing in the future is commensurate with the way we should handle that particular environment and behave in that particular environment.

We had a commission in place last year that looked at safety, that looked at environment, and that looked at health. By the way, these three areas are intertwined; you cannot separate the two. One feeds on the other. It became very clear that we had a major kind of problem that we needed to address.

That got us into conversations with OMB, and between OMB and the Foundation we agreed on a five-year program. Again, it is not something which you can clean up overnight or rectify overnight. It takes a longer period of time.

We are scheduling about $150[9] million for that particular effort. The first installment against this $150 million is in this year's budget to the tune of about $10 million.

With the chairman's permission, I would ask Peter Wilkniss to come forward and discuss the details that Mr. Buechner asked for.

Dr. WILKNISS. Mr. Chairman, Congressman Buechner, the initiative that Director Bloch described in general is focused on three areas: number one, safety. We have had some major problems, accidents, and we believe we have to attain year-round operations with modern technology, with acceptable risks, number one.

Number two, in the environmental area, we believe we have to clean up past problems. We have to bring our operations in consonance with changing attitudes, changing regulations, laws, and changing technology.

Last, not least, in this area, I believe, we have to look forward, create new approaches and new technologies to improve on what we are doing and maintain the leadership that the United States has had in Antarctic operations.

Finally, the health area. We are wanting in medical facilities. The field teams that spend sometimes months in very remote areas of the Antarctic need to be equipped with experts that have medical training to assure their safe, if not comfortable, operation.

The program that is in the President's budget has three parts. Number one, the safety part: We envision a total of about $30 million over a period of five years. It concerns itself with improvement in our air traffic control, our ship operations, the general conduct of our work in the stations—for instance, McMurdo is wanting in a sewage treatment system and fire suppression system. South Pole has major problems in the housing we are providing, again in fire suppression. The station itself is in need of repair; the same we have to say for Palmer station.

As far as the environment is concerned, you have seen for yourself that we have a major backlog of cleanup in the McMurdo area that will cost millions of dollars. We are working on bringing our waste water treatments and the burning of wastes into agreement with the new regulations that were accepted by the Antarctic countries in Hobart in September of last year. Also, we have to come into the spirit of the law, if not the letter of the law, in our domestic laws and regulations, of which approximately 101 statutes potentially apply to what we are doing.

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[9] NSF indicates that the correct number is $170 million.

And finally, you have seen the problems that we have in the health area. We had a major accident involving 11 people, nine injuries and two killed. And all we can do in the Antarctic with what we have now is stabilize those people, and then get them out as fast as we can to New Zealand.

Mr. SKAGGS [assuming chair]. The gentleman's time has expired.

Mr. BUECHNER. If I could, Mr. Chairman, I don't want to ask another question, but there were a number of complaints that were presented to this committee earlier, and they were from the Environmental Defense Fund. There were, I think, eight specific complaints that they had.

I would like to give a copy of those complaints to the NSF and ask them to give this committee some response to those particular complaints, because I think, when you line them out, they look pretty accusative. And I think there are some legitimate responses that explain why some things have not been done, and certainly, Mr. Chairman, a lot of it depends on the money that is made available to NSF, because it is one thing to say, in an unlimited budget, you can do all those things, but with a limited budget, you have to set priorities, and I think you have done a good job of it.

But I would like to have you take the time and give you the opportunity to respond to those allegations.

Thank you, Mr. Chairman.

Mr. SKAGGS. Mr. Bloch, if you could provide that for the record, we would appreciate it.

Mr. BLOCH. Yes, we will be glad to respond to that. Let me just say in general that there are some things in that document that are appropriate; there are some things in there which are wrong; and there are some things in there that would be appropriate under a very unlimited kind of budget. So we have to bring all these things together, and we will be glad to give you that answer in detail.

Mr. BUECHNER. Mr. Chairman, I would ask unanimous consent that those replies be inserted in the record.

Mr. SKAGGS. Without objection.

[The information follows:]

The Environmental Defense Fund testimony contains a number of inaccuracies. For example, EDF's testimony charges that the waters off McMurdo Station are more heavily polluted in terms of PCB levels than virtually all estuaries and bays in the United States. This is not correct.

In fact, as environmental awareness in the United States and within the Antarctic Treaty System has increased, NSF has taken a number of steps to improve environmental practices at its antarctic stations.

- In the early 1980s at McMurdo Station, dumping of trash and scrap at the edge of Winter Quarters Bay was stopped and in recent years significant effort has been devoted to cleanup of that area and the station as a whole.
- In October, 1988 an announcement and summary, "Environmental Protection Agenda: U.S. Antarctic Program" was published in the Federal Register for comment. It covered the following topics:
    - planning for environmental management,
    - legal review of responsibilities,
    - environmental assessments and impact studies,
    - environmental awareness, and an
    - update of facilities and logistics plan with an emphasis on environmental consideration.
- Significant actions in Antarctica this past season, in addition to the Winter Quarter Bay clean up included:
    - cessation of ocean dumping,
    - extensive retrograde of metal scrap, old vehicles, construction material, batteries, tires, and other waste products to the U.S.;
    - general site cleanup facilitated by introduction of strategically placed dumpsters, and an
    - underwater survey and sampling of McMurdo's marine environs results of which are expected shortly.
- The FY 1990 Budget included $10 million for the first year of a five-year Safety, Environment and Health (SEH) initiative. Of this amount about $5 million is earmarked for environmental activities for which about $30 million is planned, mainly in the first three years of the initiative. These funds will used for studies, procurement, construction, etc. related to the following topics:
    - wastewater treatment and outfalls,
    - solid waste minimization and disposition,
    - incinerators,
    - environmental monitoring, and
    - other activities determined to be of high priority.
- The Foundations's Division of Polar Programs plans to hire shortly a Safety Environmental and Health Officer, who will have environmental oversight as a key responsibility.

- On February 7, 1989 the NSF Director and staff met with representatives of environmental groups concerning the environmental part of the SEH initiative and means for implementing it. There was unanimous support for the initiative, though some thought additional actions were needed too.
- During the next year, NSF will participate in the development of a new waste handling code for Consultative Parties to Antarctic Treaty, continue to work on pollution control at United States Stations, complete its review of NSF's compliance with environmental legal standards, and revise its Environmental Protection Agenda in response to what has been learned through these and other efforts.

Mr. SKAGGS. The gentleman from California, Mr. Mineta.

Mr. MINETA. Thank you very much, Mr. Chairman.

Let me follow up on Mr. Buechner's question about the Antarctica program. Given your current fleet of aircraft there, is that fleet sufficient to meet your current, immediate requirements?

Mr. BLOCH. No, the fleet is not sufficient to meet our requirements. In fact, many times we probably could not undertake programs that we would have liked to undertake because of the limit—not necessarily because of total dollar limitations—because of limitations of aircraft availability.

Mr. MINETA. Now, given the fact that you are going to be doing increased research in the Antarctica with the near doubling of the NSF budget by 1993, what, then, kinds of plans are you incorporating into that aspect of it in terms of the future aircraft requirements to support the increased research activities there in Antarctica?

Mr. BLOCH. Well, for the immediate future, the next few years, we have an ongoing program to upgrade and improve the existing fleet. As you know probably, we rescued one of the LC-130s that was stranded in Antarctica for years. It is being rebuilt right now in New Zealand.

Mr. MINETA. But that will not be ready until 1992, as I understand it.

Mr. BLOCH. Well, I understand, but that is part of looking at the immediate future.

We have had access to some intermediate aircraft, small-size aircraft, which we can use in certain areas, but for the long haul, we are trying to develop a strategic plan to tell us what kinds of requirements we have from the 1994-1995 time frame on. And we have to deal with that one in future appropriations.

Mr. MINETA. In your NSF budget submission, there is a statement on USAP-2 saying, "Upgrades of the LC-130 aircraft and construction activities will continue but at a slower rate." So, given the programmatic efforts being doubled by 1993, I just was a little concerned about whether or not this part of it was going to be staying in pace with it; that is all.

Mr. BLOCH. Mr. Mineta, as was pointed out this morning, you know, requests are one thing; appropriations are something else.

Mr. MINETA. Oh, absolutely, and being a member of an authorizing committee, we don't appreciate but we recognize the distinction. [Laughter.]

Thank you very much, Mr. Bloch. I really want to commend you and the job you are doing at NSF, as well as to those on the National Science Board.

Thank you very much, Mr. Chairman.

Mr. SKAGGS. Thank you.

The gentleman from Illinois?

Mr. BRUCE. I thank the chairman.

Your 1990 budget doubles the number of Science and Tech Centers in the second year of the program. This committee has been reluctant to approve new centers. What is the rationale for the doubling of the number of Science and Tech Centers this quickly, and how does that fit into your being able to adequately fund existing centers and other national facilities?

Mr. **Bloch**. Well, the rationale behind increasing the centers in the 1990 budget, as we described, is the same rationale that we had in establishing the centers in the first place. It is a way of operating in the research environment where large problems beyond the capability of a single investigator are at issue. It is a way of operating and doing research in sophisticated areas where you need major equipment.

It is a way of operating on a research problem, in a research area where you need interdisciplinary involvement, where it is not a question of mathematics or of physics or of chemistry or of biology but all of the above combined. That is the rationale for it.

Our total expenditure in the Foundation on all center activities, not just the ones you mentioned but the Engineering Research Centers, the Materials Research Laboratories, which have been in existence for 10 or 15 years, for instance, is less than 10 percent—it is about 6.5 percent right now—of the total budget of the Foundation.

So it is again—you know, the word "balance" has been mentioned too many times this morning; I will mention it once more. The balance between individual researchers and centers and group activities is what we are after.

That we want to increase the Science and Technology Centers this year, you are saying, so fast? I don't think it is so fast. Let me give you some numbers. When we went out with our solicitation last year, we got over 300 replies, 350[10] replies. When we went through all of the replies, went through peer review with them, there were 48 centers that were judged to be of outstanding quality and pertinent to the issues of the day.

Out of the 48, we only could fund 11. So that is how far our money went. So 11 out of 350 is a very small number. The yield is very low, and we think we should follow through in 1990 on the second round because of this high demand that we have and the good science that we saw and the good activities that we saw coming out of the first solicitation.

Maybe Dr. Moore wants to add something to that.

Dr. **Moore**. I was going to make essentially the same point, that the decision process this time around was exceedingly difficult. And the reason it was so difficult was the very high quality and exciting science opportunities that were represented in the proposals that we received.

The other point that you mentioned is whether we will be fully funding the ones that we establish this year. And to that, the answer is that the budget submission as we have presented it indeed does provide for full funding for each one of those centers.

Mr. **Bruce**. Did you make a management decision as to what happens if you do not get full funding?

Dr. **Moore**. Well, if we do not, we will have to decide what to do at that point.

Mr. **Bruce**. But there is no present management decision as to where you go with new centers versus maintaining existing centers?

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[10] NSF indicates the correct number is 320 replies.

Dr. **Moore**. We clearly have a responsibility to maintain those that we have established; there is no question about that.

Mr. **Bruce**. Well, then, let's delve deeper into your decisionmaking process. Under the facilities management modernization program,[11] in your fiscal year 1990 budget, did you request any funds to OMB for that new program, facilities modernization?

Mr. **Bloch**. On the facilities modernization, we had a number of discussions on that, and there is no funding provided in the 1990 budget for that.

Mr. **Bruce**. Right. Did you ask OMB for money?

Mr. **Bloch**. No, we did not.

Mr. **Bruce**. So that was a management decision not to fund the facilities modernization program?

Mr. **Bloch**. Well, let me tell you why.

Mr. **Bruce**. All right.

Mr. **Bloch**. We were asked by Congress to put a report together on the facilities that elicits many of the issues that need to be resolved. We are in the process of doing that. That will be completed in the June time frame as requested.

We established a facilities office, with senior people in it in the Foundation, to get a move on on this particular problem. So I think we are on the track of establishing not only what the requirements are—we know the requirements—but how to deal with that particular issue, because the authorization bill is very precise in some areas and very prescriptive in some areas. And we have to see what that really means in practical terms, and we are in the process of doing that.

Mr. **Bruce**. Does it concern you at all that at one part of your budget you are expanding programs, like in the Science and Tech Centers, and in another program you are studying whether or not you ought to modernize existing facilities, and maybe the program ought to be studied whether you start new facilities and updating and modernizing the existing facilities? We are launching off onto new programs but studying whether or not we ought to keep existing programs.

Mr. **Bloch**. No, it doesn't bother me at all because you should understand what we have told Congress over and over again, and Congress has agreed with us on that. Our priorities are people, equipment, and instrumentation, and then facilities. That was a deliberate policy decision. The National Science Board agreed with it. I think that is in line with the need of the country.

Yesterday, in an appropriation committee meeting, we had exactly the same discussion, and the opposite view from yours was presented.

Mr. **Bruce**. To start new centers and don't modernize old ones?

Mr. **Bloch**. No. Go focus on people and equipment before you focus on facilities.

Mr. **Bruce**. How does that fit into your astronomy program where, over the last several years, there have been significant constant-dollar declines in assistance to astronomy; yet you are funding a major new project, the Very Long Baseline Array? If you propose new construction, is there a plan for closing down existing facilities at all?

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[11] Academic Research Facilities Modernization Program.

Mr. BLOCH. I think we have a semantics problem. The authorization bill, when it talks about facilities, it means the maintenance and upgrade of brick-and-mortar facilities, the way I understand it.

What you are citing is construction of new equipment. It happens to be a big piece of gear, obviously, and it involves some brick and mortar, obviously, somewhere. But that is in a different category, and when I gave you the answer I did, I put that one into the second priority category of instrumentation and equipment. So the two are not the same.

Mr. BRUCE. But your dollars going toward astronomy have not increased and have been in decline if you take constant dollars. Is that not correct, over the past several years?

Mr. BLOCH. I don't have the numbers in front of me, but I will be glad to look it up. It has not increased very much, but we have put a large effort into it. We are spending on the VLBA that you are citing close to about $80 million to $90 million in total. We have been spending it since 1984. We would have liked to spend it at a faster rate so that that piece of instrumentation would be complete by now. We had to stretch it out because of fiscal constraints that we had.

Dr. MOORE. Could I make one comment, two comments, actually?

Mr. BRUCE. Surely.

Dr. MOORE. First, on the astronomy, you have to bear in mind that VLBA was the number one priority of the astronomy community. As part of our decision process, we took that recommendation seriously, and we have been putting more money into that particular arena, or that particular project, in line with that setting of priorities.

The second point on what Mr. Bloch just said on semantics, the S&T Centers are not facilities. At least we do not fund facilities at the S&T Centers. Those are research activities, and most of the funding goes for people, investigators in those centers, and then a smaller but significant factor for instrumentation and equipment that those people use.

Facilities, in the sense of this committee's authorization, have been provided in a number of cases to especially the Engineering Research Centers by now, and I am sure the same thing will happen in the STCs, by other agencies, the States in particular, for those. But I think it is important to understand that the centers themselves are not facilities in the sense of the authorization bill.

Mr. WALGREN [resuming chair]. The gentleman's time has expired.

Mr. BRUCE. All right. I will come around the second round, then.

Mr. WALGREN. All right.

The gentleman from Iowa, Mr. Nagle.

Mr. NAGLE. We have had, Dr. Bloch, in all candor, some rather disturbing testimony last week and the week before with regard to the status of the science and mathematics and engineering achievement levels of students in this country.

Dr. Boyer, who is the president of the Carnegie Foundation, came, and as succinctly as I can give you his testimony, he says, "The harsh truth is that science and mathematics education in the Nation's schools is in bad shape."

He then recites a litany of shortcomings of America's high school mathematics accomplishments, and then he says, and I am quoting from his testimony, "In science, the crisis is equally disturbing. Again, the most recent science report card, 'Trends and Achievements Based on the 1986 National Assessment,' reported that . . ." and then again another litany of shortcomings of American high school and undergraduate students' scientific achievement.

I guess I can surmise that the basic position of NSF is that this is the responsibility of the States. I gather that from your own testimony, if I may quote it to you:

> NSF's pre-college support has increased dramatically since 1983. Nevertheless, the NSF role in pre-college education is very small in relation to Federal and State support for education and focuses only on science and mathematics. We can lead and stimulate others to lead and to innovate. The States, which bear the principal responsibility for education, must step forward with renewed efforts in this area.

So, first of all, it is your position that this is a problem that the States ought to address; it is not a national concern, predominantly?

Mr. BLOCH. No, not at all. I think you are reading that statement not the way it is meant. What we are saying essentially is that the Federal Government or NSF, if you please, has a role, has a significant role, but it does not have the total role for the solution of that problem. And we are focusing in that statement essentially on the States and the localities, as is the case. They are participants in it.

In fact, you were not here this morning when a conversation along that line between Mr. Brown and myself came up, and his focus was, how come in the 1960s the reforms that were put in place, the programs that were put in place, did not have a permanent kind of effect? In my opinion, it was the fact that these were stand-alone programs. They were not cemented in with those of the localities and the States. There was no participation, or enough participation—I am sure there was some—to make these programs permanent and lasting.

We are not stepping away from this obligation; quite the contrary. But we are saying we are not the only ones that can solve that particular problem. So I think our statement might not be a very good expression of this, but what we mean by it essentially is that we can be a catalyst. We have a role to play, but we are not the only ones that have that role to play.

Mr. NAGLE. But your testimony seems to imply that it is the principal responsibility of the States and not of the national government.

Mr. BLOCH. Well, the localities certainly have the principal responsibility. Every school board has a responsibility on teacher selection, on teacher pay, on materials selection, and so forth. And those are important aspects of the solution to the problem.

Mr. NAGLE. Well, would you concur with Dr. Boyer's——

Mr. BLOCH. We got into trouble in the past, by the way, when it was assumed or thought of that we were trying to impose a materials development program on the country. We are not doing that and never did that, but it was only looked at and the specter raised. We got into trouble on that. So there is an acknowledged role of the localities.

Mr. NAGLE. But you would concede, or would you disagree, with the testimony received from Dr. Boyer and the Carnegie Institute that, whoever's responsibility it is, we are not getting the job done?

Mr. BLOCH. I don't disagree at all. I don't disagree at all; quite the contrary. I have made similar comments myself.

Mr. NAGLE. Then we had Dr. Bell in, and he talked about NSF's role and the SEE program. I would like to read you a quote from his testimony and ask you to respond. He said, and I am quoting:

> Two years ago, there were definite signs that NSF was going to make a major positive move to reassert its leadership and concern for the health of undergraduate education, such as it had in the middle sixties. Under the leadership of Homer Neal, the National Science Board produced a report on undergraduate science, engineering, and mathematics education that called for major initiatives at NSF.

Continuing the quote:

> Last year, we looked with hope as the Division of Undergraduate Education was established within NSF, within SEE, and we were at first encouraged by the rhetoric announcing NSF's plans for undergraduate education. But a closer analysis has turned the hope to disappointment and finally to dismay.

Is that an inaccurate assessment?

Mr. BLOCH. Absolutely.

Mr. NAGLE. And why so?

Mr. BLOCH. Well, I will be glad to answer, but let me ask Dr. Powell to take the lead in answering that question. He is from the National Science Board. The National Science Board has spent a lot of time on this particular issue, and we are spending a lot of money on it. But I will let Dr. Powell answer.

Dr. POWELL. Good morning, Mr. Nagle.

Mr. NAGLE. Good morning.

Dr. POWELL. I am a member of the Science Board, I was on the Neal Committee, and I am at an undergraduate institution, so I have a special interest in this particular question.

I think that statement is overly harsh. We could always be spending more money on any of the areas that we have identified this morning. I think we have made significant progress in spending for undergraduate education.

We are following the broad outline of the Neal recommendations; and, considering what has happened to the overall Science Foundation budget since that report came out, I don't think we are doing too badly. More growth is planned for the future, and I think it is necessary.

But if you recall—I don't know if Mr Boyer said this when he was here last week, but he is fond of saying that education is a seamless web, which is something I very much agree with, from kindergarten to graduate school. And so we can pick out individual areas. We are probably not spending enough money on any of them. But if we look at the whole and the pattern and the balance, I think we are not doing badly.

Mr. WALGREN. Would the gentleman yield?

Mr. NAGLE. Certainly.

Mr. BLOCH. Could I just answer?

Mr. WALGREN. Sure, certainly.

Mr. BLOCH. Mr. Nagle, Dr. Powell was very polite when he called that judgment of Mr. Bell's harsh. I think it is irresponsible, and I will say that with thinking about the choice of my words because we went, in a two-year period, from zero, practically zero, to over $100 million in our 1990 request for undergraduate education. And I think that is a significant commitment of the Foundation, and I don't know why that statement is being made the way you read it.

Mr. NAGLE. I didn't say it, you understand.

Mr. BLOCH. I know. I know, you are quoting. But I don't know why the gentleman made that statement.

Mr. NAGLE. Let me yield to my chairman.

Mr. WALGREN. Well, perhaps you want to pursue that point by point. My question was, if the gentleman would yield, certainly we could spend more, but I don't think that is the end of the question because at some point the public has to see what we should spend as opposed to what we could spend. Because the truth is, we could draw money from lots of other areas than you are confined to if we knew what the "should" was.

Now, it is certainly true that this area has come back strongly, and perhaps it is at a rate that is prudent. But that still does not answer the question, what should the national investment be?

Now, take, for example, we had one measure of the "should" just in in-service training from the National Science Board. Is that right? Did it come from the National Science Board? In 1984, the measure was $350 million a year. You might say, well, we were spending zero in 1981, and we are spending $46 million there, and we could spend more. Well, you are doggone right we could spend more. And so what I am interested in is what is the "should" number?

Now, if you took the idea that we should spend—let's say, as I understand it, that $350 million was designed to accomplish what should be done in in-service training in a period of five years. Let's give us 10 years to accomplish that, and let's say we just spend half of what they say we should spend. That would be $175 million a year. And then if you add that $175 million, the hard number that you have in SEE, in that particular education directorate, you would come up with a budget of $319 million instead of your projected budget of $190 million.

What can you tell me about what the "should" number is for the public? The public turns to us, and they say, "What should you be spending?" And they would like us to have the ability to take from the military and to take from agriculture subsidies and to take from whatever else and meet what we should do.

Now, my question to you is, what is the advice? What should we do?

Mr. BLOCH. The answer to that question is, you are going to get as many answers as you are going to ask people. But in the undergraduate area that we were just discussing with Mr. Nagle, the National Science Board, with one answer, came up with a program, with a strategic program, that spelled out in fair detail on a year-by-year basis what should be spent.

Let me recite it. In year one, the National Science Board said we should spend $63 million; we spent $64.4 million. Let me tell you, that is in year one that the National Science Board had in mind. It was a year earlier than we started, but that was because of Gramm-Rudman and budgetary constraint.

In year two, the National Science Board talked about $113 million; we are asking $105 million in the fiscal year 1990 budget. So the two are pretty much the same. That is one view of the world. I am sure, if you ask the gentleman who was quoted before, he has a different number.

Mr. WALGREN. No, but I would like your view of the world, and I would not like the view——

Mr. BLOCH. That was what the National Science Board was telling us, and we are going down that particular road.

Mr. WALGREN. All right.

Mr. BLOCH. In fact, today there is a review of how we are spending that money because in certain areas we are deviating from the National Science Board's view of where we should spend it, and that is a fair discussion to have.

Mr. WALGREN. But again, if the gentleman would continue to yield, we go back to this point that I understand that the numbers that you send up here are "could" numbers. They are numbers that you can do, that you feel that, given the whole range of limitations that you face in the system, those are numbers that you can do.

But at some point, we have to measure what we can do against what we should do. And I am just curious, what would you say we should do in these years in the Science Education and Engineering Directorate?

Mr. BLOCH. I will be glad to give you that input for the record. But in the end, Mr. Chairman, we have to submit a budget that fits in with the total priorities of the administration and the executive. I know you understand that.

Mr. WALGREN. Yes, and you can have a lower number. I mean, I gather there would be a lower number in the budgetary sense, and I can appreciate that.

Mr. BLOCH. But we have strategic plans for the education area, certainly, for the undergraduate area, for many of the science areas that talk about bigger spending than what we are achieving in our budget request or in our appropriation.

Mr. WALGREN. What are those strategic plans?

Mr. BLOCH. There is a gap between our request and the appropriation, as you know very well.

Mr. WALGREN. Yes. What are those strategic plans that would set targets for spending, aside from the budget submission and the budget request?

Mr. BLOCH. What are the strategic plans? I don't understand the question. What do you mean?

Mr. WALGREN. Well, you just said that you had strategic plans to look at what you should be spending in science, if you could, that have different numbers than can be supported in a budget request document. And I can understand that. But what are those numbers?

Mr. BLOCH. I cannot quote them right now, but we will be glad to make that available to you.

Mr. WALGREN. Can you give us a ballpark now? I mean, there must be a threshold level here. We are at $190 million. Would you be comfortable with the $319 million, which is essentially one-half of the National Science Board's estimate of what in-service teacher training should be, plus the actual recommendations that you have been able to support in a budgetary sense with the administration?

Mr. Bloch. Sure, I would be comfortable because that is exactly the point we have made in the doubling request of the National Science Foundation's budget, that we would—and, by the way, SEE is doubling at a faster rate in that envelope than the rest of the Foundation.

But I want to warn about one thing. Dumping money into areas from one day to the next is not a good idea. We need to have programs in place. They have to be built up in a considered kind of way, and just throwing money on the problem does not mean that that is useful spending. That is why our cautionary approach to the increases, and that is why we are not asking for doubling in one year, by the way.

Mr. Walgren. I thank the gentleman for yielding.

Mr. Nagle. Well, I am probably going to cost Mr. Bell future employment. [Laughter.]

But he also said that the problem at NSF—and I am paraphrasing him because it was in response to a question rather than in his written testimony—I said, "What's the problem in NSF, in your judgment? Why aren't they more aggressive in the areas of education?"

He said that, basically, NSF regards itself as a research agency. They don't really think that this is a role that they ought to have to undertake. And you would respond?

Mr. Bloch. Yes, that is patently wrong.

Mr. Nagle. Patently wrong?

Mr. Bloch. Yes. And my statement addressed that problem, that the role of NSF maybe at one time—and I am not even sure of that, by the way; in fact, the numbers that the chairman just quoted belie that statement—maybe at one time that was the role of NSF. NSF's role is not science, and it is not research only. It is a lot of things, and education is one of them. And we are taking that role very seriously.

The development of human resources is another one. We are taking that role very seriously. And if you look at our total budget, you see that those areas have gotten the major increases, well beyond what the research areas have gotten. So I reject that kind of statement.

Mr. Nagle. But I guess you would concur, in response to the chairman's questions, that that is what we are spending, not what we should be spending.

Mr. Bloch. No, but what we are spending makes the point that we are focusing on education. We are focusing on the development of human resources. Yes, we are focusing on research, but not exclusively. And I hope this Congress sees us in a different light than in that very simplistic kind of approach that it is a science agency. We are not a science agency only. We are looking at engineering, we are looking at education in equal amounts.

Mr. Nagle. Well, doctor, I am, of course, a fan of yours, and I have been long supportive of NSF, and my voting record reflects that. My voting record reflects my adherence to the peer process, which I think is the best pursuit. But I do have to differ with you a little bit on the philosophy that this is a predominantly State responsibility.

I share, I guess, the chairman's concern about the fact that we get numbers that say this is what we can do rather than this is what we should be doing, and I share his interest in those figures.

Now let me ask you about the facilities bill, the Roe bill, because in addition, of course, to having more investment in undergraduate education. We also have to have facilities. And I noticed that the budget does not request any money under the Roe bill to modernize facilities at junior colleges and colleges. Is that an example of the commitment that NSF has to undergraduate education?

Mr. **Bloch**. I addressed that question before. Let me address it again.

Mr. **Nagle**. In this context?

Mr. **Bloch**. Yes, as much as I can.

Look, first of all, the facilities provision of the authorization bill address research facilities, not instructional facilities. So I don't quite know how that has a bearing on the undergraduate area, but leave that aside.

Mr. **Nagle**. Let me stop you right there and bring in the testimony from last year that indicates that you have got a better chance of getting a Ph.D. in math, science, or engineering if you go to a smaller college than if you go to the ones we see playing football on Saturday afternoon, because students at smaller colleges get to work with professors, and professors need research projects.

Mr. **Bloch**. That is why we have programs that address the research in undergraduate institutions.

Mr. **Nagle**. But we do not address the need for modernization of those facilities by not asking for any money under the Roe bill.

Mr. **Bloch**. I will get to the modernization now. No, it is true; there are no dollars in the 1990 request for facilities modernization. We have, however, set in place what that authorization bill asked us to do, namely, to come up with a report by June 30 or June 15, whatever the date is, that takes into consideration what the provisions of that authorization act are. And we have set up that office, and it is working very hard on that particular report. And after we see that report, we are going forward. We will see how we move forward, and we will keep you informed on it.

But let me mention one thing. The request for facilities money is on top of the doubling of the Foundation's budget, and that was acknowledged by this committee when it put the numbers into this year's authorization bill. I just want to remind you of that.

Our request that we have in front of you is in line with the doubling of the Foundation's budget exclusive of the facilities area.

Mr. **Nagle**. And let me remind you in closing—and I thank the chairman for his generosity in time—that I understand that you are both an agency head and also a messenger of the administration's priorities, which may not be your own. But let me say, and address my comments to the administration, that after eight years of the decline of the technological capabilities and achievements of American high school students and undergraduate students; the fact that Japan will produce more Ph.D. candidates by a third on half the population than this country can with twice the population; the fact that half of our graduate students at Ph.D. levels are now foreign citizens; and the dismal, dismal record of achievement of math, science, and engineering students, the high school students of the United States—not directed at you personally, doctor—but I think the administration is failing to recognize that there is a heck of a crisis in this area, and it has utterly failed with this budget to respond to it.

Mr. BLOCH. Mr. Nagle, I have made similar comments.

Mr. NAGLE. See? I knew we would agree——

Mr. WALGREN. The gentleman's time has expired. [Laughter.]

The gentlelady from Maryland, Mrs. Morella.

Mrs. MORELLA. Thank you very much.

I have been very interested in the fact that we are putting money into programs and NSF has increased its funding in other areas, and yet we are not putting money into people. I have noticed the difficulty that we have recruiting and retaining in, let's say, the National Institutes of Health, that lost like 41 people to a cancer institute of a university because of the pay.

I know that NASA is having difficulties. Are you having any difficulties with NSF in recruiting and retaining, Dr. Bloch?

Mr. BLOCH. Yes, we do. Let me give you—we are in a slightly different situation, but nevertheless equally critical, than the National Institutes of Health, for instance. They are running laboratories. We are not running laboratories. But we depend on highly qualified science and engineering researchers to come into the Foundation and to be essentially our professional staff, and we have a hard time attracting people of this sort because of the discrepancy in pay between the academic sector and the government sector, not even talking about the industrial sector and the government sector.

I deplore the fact that the salary increase that was contemplated for the SES area did not go through, and I think that that is something that needs to be fixed and needs to be fixed very quickly because what you are winding up with in the future, if that is not being addressed, is that you are not being able to fill the jobs with the right people with the right background and that you are solely then depending on people that either have already retired and therefore do not need that as a first income, or you are depending on junior kinds of people that don't have the experience and the wisdom that is required to fund our program. So you are spending a lot of money, and we should have the best people to do the particular jobs.

Mrs. MORELLA. Can you give instances—if not specifically now, could you submit to us some instances of areas where you have had difficulty by virtue of the salary and the fact that these people would be frozen in at a limit in recruiting or even retaining if they can leave?

Mr. BLOCH. We will gladly give you some examples of that.

Mrs. MORELLA. I think it is important that we compile some of these things in order to do something more with increasing the SES salaries, which have been held back.

[The information follows:]

The following examples demonstrate the difficulty encountered by NSF in attracking and retaining senior scientist and engineers. The divisions of Chemistry and Materials Research operated with acting division directors for several months.

The previous incumbents of those positions—both long-term NSF employees—moved to senior administrative positions at universities, with salaries well in excess of $100 thousand a year. The Assistant Director for Mathematical and Physical Sciences has recently accepted the position of Executive Officer at the AAAS, and press reports of his salary suggest that it exceeds even the salary he would have received had the proposed SES salary increases taken effect. The prospect of replacing him is an daunting one, made more difficult by the maximum salary level of $80,700.

Mrs. MORELLA. Right now, what are you doing? You said something about makeshift. How are you handling it now?

Mr. BLOCH. Well, we are handling it today by, first of all, where the search for people takes more time, so in many areas we have openings that we cannot fill for seven months or a year. And that is not good either, by the way, because these are division directors' jobs, for instance. And having an opening for a year is not very helpful. We have had seven months and twelve months, respectively, on two openings that we had, one in chemistry and one in materials sciences.

Secondly, we also cost-share many times on a rotating kind of basis, bringing people into the Foundation; and, the sending institution, a university most of the time, is paying part of the cost of the salary. You can only do that so often, and you can only do it with certain universities. Or again, you have not equal access to all the candidates that you should have.

That is one way of helping ourselves. Even there, we are limited, by the way, because we have a cap of $95,000 on top of that, when a lot of the salary out in the universities is $105,000, $110,000, and $120,000. So we cannot even attract enough of the people because of that cap limitation that we have on IPAs.

Mrs. MORELLA. Your suggestions, then, to Congress would be——

Mr. BLOCH. My suggestion is very simple. Go divorce congressional salaries from everything else and focus with the salaries on the SES and non-SES categories. And make it more akin to what you have to pay for in the marketplace. Today we are under, I will say, by 50 percent. That is a big discrepancy.

Mrs. MORELLA. I think we have got to educate Members of Congress that we cannot live by the adage that government governs best that pays least. [Laughter.]

I think they have to know that. I am trying to do that, and I am getting examples that frighten me in terms of the desperation of the situation.

Mr. BLOCH. Look, we are spending close to $2 billion. Let me take one example. In one directorate, we are spending $500 million. We have a cap on the salary of the assistant director who runs that directorate, which is $80,000, give or take a few dollars.

For something like that, a $500 million enterprise in industry, you would get $200,000 on a going rate. That individual has to be a good manager. He has to be a good scientist. He has to have knowledge of scientific areas that span a broad range of topics from astronomy to materials science, and so forth, and I don't think we should run it with a junior engineer in there. Not that the individual is; I don't mean that. [Laughter.]

But that is the problem we are up against.

By the way, he is leaving and is going to greener fields. [Laughter.]

Mrs. MORELLA. There you go.

Mr. Chairman, is it all right, if Dr. Bloch wants to put anything else into the record attendant to that, that he be allowed to do so?

Mr. **Nagle** [assuming chair]. Without objection, it shall be so ordered.

Mrs. **Morella**. Great. Thank you.

[The information follows:]

The following charts display the salaries at major research universities and industry. The university figures represent full year, full professor salaries at institutions with more the $30 million per year in Federal Research and Development funds. The industry salaries represent Ph.D scientist and engineers by field.

University Salaries

	Public	Private
Bioscience	$ 75,107	$ 87,875
Computer Science	92,109	107,768
Mathematics	76,153	89,099
Engineering	87,065	101,866
Physical Science	78,000	91,260

Industry Salaries

	Average	90th Percentile
Air, Earth, Marine	$ 73,656	$ 98,736
Chemistry	81,180	101,376
Physics	81,048	104,016
Biological Science	81,972	118,800
Mathematics	76,164	92,928
Computer Science	81,444	116,028
Electrical Eng	82,500	104,544
Mechanical Eng	78,672	97,416

Despite this growing salary problem we have used a variety of approaches to attract capable scientists and engineers.

- Senior individuals are available to us, for example, when they reach retirement age and their government salary is a supplement to their retirement income.
- Senior individuals are also available to us by using the IPA authority, though we are now restricted from contributing more than $95,000 to their salary from government funds.
- On rare occasions we can recruit senior people from industry on a totally volunteer basis.
- And individuals are available to us, as I mentioned, if they are willing to take a pay cut in order to fulfill a public service objective.

Mrs. Morella. Mr. Chairman, I would like to ask Dr. Bloch just one other thing if he has an answer at this point. How are your programs—I know you have, I think, six new programs that deal with excellence for minorities in science and engineering. I am very concerned that we have not been attracting early enough minorities, and I put women into that category because I think there is a real need for women to be involved.

I know you have a lot of programs. I looked through all this material here. But I think those programs, whatever it is called—Excellence in Education for Minorities—I am wondering if you can give us any gauge of whether any of these programs are working. Do we have anything that shows that they are working?

Mr. Bloch. Well, these programs have been put in place over the last 3, 4 years. They all are being monitored very thoroughly. We have evaluation criteria that go with these programs. We can show you some and be glad to supply some statistics on it, how many people participate and what has happened to the people afterwards.

It is a limited time horizon, I want to say. We need a longer time horizon. So we are very concerned not just to put programs in place but also to put some evaluation criteria in place. All of our pre-college programs that have been discussed this morning have these evaluation criteria in place, and we would be glad to supply you with some insights.

Mrs. Morella. I would very much like to see any of the evaluation materials that you may have and, also, you were going to expand—any of your centers where you have the town, the business community working with the school systems, working with the universities, and you have some programs like that, are you going to put any of them in other areas, like around the Washington, D.C., area? [Laughter.]

Mr. Bloch. Well, we have some there.

Mrs. Morella. You have one at Howard, I think. But do you have anything——

Mr. Bloch. We have one in Howard, yes. We have an Engineering Research Center at University of Maryland in College Park.

Mr. Nagle. I think what she is asking is, do you have any plans to put one in a specific congressional district of Maryland? [Laughter.]

Mr. Bloch. Mrs. Morella has to be more precise.

Mrs. Morella. We could supply that. But you are planning to expand, though, in general?

Mr. Bloch. Well, yes, we are going to expand a number of these programs. The Science and Technology Centers program is expanding; the Engineering Research Center program is expanding; the Industry-University Center program is expanding, also. There are about 50 of those right now going up, some of them falling out because their time frame has expired. But they are stand-alone, and they are on their own, and they are doing pretty well. The answer is yes.

Mrs. Morella. I thank you. I want you to know that NSF has a very high-quality reputation in the circles in which I travel, and I appreciate what you have done to make that possible, and all of the others who are here.

Mr. Chairman, I want the record to show that you have been an exemplary chairman. [Laughter.]

Thank you.

Mr. NAGLE. Mr. Bell dissents. [Laughter.]

Let me ask you a question for the record, if I can. This is not for Mr. Bell.

The question the committee has asked me to ask is: Would you review the NSF plans regarding replacement of the radiotelescope at Green Bank, West Virginia? Where does replacement of this telescope rank relative to the other proposed new facilities for astronomy?

Mr. BLOCH. Let me step back for a minute and give you the history of what went on there.

We had a telescope in place in Green Bank, West Virginia. Green Bank, West Virginia, is a site that was established many years ago, 30 years ago or thereabouts. It is a very special kind of site because the environment for it has been protected inasmuch as it is a radio-free kind of zone, about the only one that probably exists. I am not absolutely sure on that.

There were two radiotelescopes that were in place there. One of them collapsed last December,[12] completely destroyed. We don't know the reason why yet; we are looking at that.

The obvious question that came up right away was: What do we do with this particular site, because it is a very important site? It has very good infrastructure in terms of shops, in terms of people, in terms of facilities in general. And with the collapse of that telescope, the site is somewhat crippled. There is still the other telescope there, and there is a Navy installation, also, there.

So we looked at potential replacement ideas. One that was discussed and has been in the meantime fleshed out, is a radiotelescope of a different design than the one that collapsed, because 25 years have gone by and technology has moved on. And we have looked at that particular approach and that particular design to see what it could yield.

It is a good approach to life. It is a modern telescope. It improves the sensitivity. It broadens the application range. It uses new materials, new panels, and so forth.

In the process of looking through the Green Bank issue, we also found that it was a site that was considered a few weeks before—already before the collapse, for a gravity wave detector program, which is not funded, I should tell you, in the 1990 program but which has gone through a lot of peer review—which has gone through the review of the National Science Board and will be in one of our budgets either in 1991 or in 1992.

And so we are looking—we have been looking at both of these approaches for the use of that particular site. That is about where it stands right now. We have had a number of conversations with interested parties from the State in it. Senator Byrd and Senator Rockefeller have been involved in it, and we are continuing that discussion, obviously.

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[12] The Green Bank telescope collapsed on November 15, 1988.

But both of these proposals have been looked at, but the funding for either of the two is not in the 1990 budget.

Mr. NAGLE. Let me ask you just before we leave, because I have been doing some work independent of this committee on the whole question of Federal salaries, and I was struck by your comments on page 12 of your testimony regarding the problems you are having in retention of qualified personnel because of salary caps.

You may have already talked about this; but, if you have not, could you address the question, have there been any recommendations within your agency for a reform program to address both the question of salary equity but also salary reform to enable you to compete in the private sector?

Mr. BLOCH. We have not had any specific proposals, no. We have been working with other people in the government and with the Volker Commission when the Volker Commission was active. We gave them some of our information, some of our problem areas, but we have not come forward, ourselves, with a reform proposal for salaries.

Mr. NAGLE. Well, I would be interested, if you want to, I would be interested personally—and I think the committee would be, too—in any specific recommendations or areas of exploration where we could get to the question of salaries and reform, because I can appreciate the dilemma that the agency has in terms of retention.

Mr. BLOCH. We will be glad to do that.

Mr. NAGLE. Now, I would like to ask you to submit for the record the NSF initial budget request to OMB for fiscal year 1990.

Mr. BLOCH. Our original request to OMB was $50 million higher than what you see in front of you, the bottom line.

Mr. NAGLE. The committee would like to ask you to submit the specific budget request to OMB for 1990, the specific document as well as the divisions and subdivisions.

Mr. BLOCH. We will submit to you the detail of the budget that we requested.

Mr. NAGLE. I want to be very precise on this, Dr. Bloch. We want the specific documents that you submitted to OMB, your budget request for 1990. Is there a problem in giving us that material?

Mr. BLOCH. Let me take that under advisement.

Mr. NAGLE. We normally request that from other agencies. I mean, it is not——

Mr. BLOCH. Well, that is why—I have never been requested that. We always have been asked that we supply the numbers, which we have done.

Mr. NAGLE. I think I am going to the chairman's inquiry of not what can we spend but what should we be spending, from your assessment, unpurified by OMB and their budget constraints and their different priorities. We would like the pure document. We may be able to be of some help and we may not. But we cannot if we don't have the numbers.

Mr. BLOCH. Well, I have no problem with supplying the numbers, but let me take the rest under advisement.

[The information follows:]

The following table submitted to OMB displays the National Science Foundation's budget request for FY 1990:

SUMMARY OF FY 1990 BUDGET BY APPROPRIATION

(Millions of Dollars)

Activity/Subactivity	FY 1988 Actual	FY 1989 Request	FY 1989 Current Plan	FY 1990 Request
RESEARCH AND RELATED ACTIVITIES				
Biology, Behavioral and Social Sciences				
Molecular Biosciences	$44.60	$48.34	$48.34	$54.42
Cellular Biosciences	54.24	57.60	57.60	61.86
Biotic Systems and Resources	59.04	65.29	65.29	78.92
Behavioral and Neural Sciences	43.78	46.50	46.50	49.73
Social and Economic Science	30.15	32.59	32.59	33.65
Instrumentation and Resources	34.15	38.42	38.42	43.42
Total BBS	265.96	288.74	288.74	322.00
Computer and Information Science and Engineering				
Computer and Computation Research	19.95	22.30	22.30	24.86
Information, Robotics and Intelligent Systems	17.01	19.85	19.85	22.41
Microelectronic Information Processing Systems	13.24	16.00	16.00	20.06
Advanced Scientific Computing	44.34	55.80	55.80	71.90
Networking and Communications Research and Infrastructure	11.55	17.68	17.68	27.27
Cross-Disciplinary Activities	17.03	17.50	17.50	21.50
Total CISE	123.92	149.13	149.13	188.00
Engineering				
Chemical, Biochemical, and Thermal Engineering	28.90	31.90	31.90	34.78
Mechanics, Structures, and Materials Engineering	25.78	29.05	29.05	31.01
Electrical, Communications, and Systems Engineering	23.38	25.28	25.28	28.12
Design, Manufacturing, and Computer-Integrated Engineering	15.39	17.67	17.67	20.01
Emerging Engineering Technologies	16.59	19.44	19.44	22.28
Critical Engineering Systems	25.11	28.26	28.26	30.10
Cross-Disciplinary Research	36.33	43.36	43.36	52.70
Total ENG	171.48	194.96	194.96	219.00
Geosciences				
Atmospheric Sciences	96.33	104.25	104.25	110.96
Earth Sciences	51.29	59.27	59.27	68.47
Ocean Sciences	135.38	146.52	146.52	154.23
Arctic Research Program	8.34	10.84	10.84	13.34
Total GEO	291.34	320.88	320.88	347.00
Mathematics and Physical Sciences				
Mathematical Sciences	63.67	67.97	67.97	73.27
Astronomical Sciences	86.02	90.04	90.04	94.54
Physics	118.21	126.71	126.71	134.15
Chemistry	94.27	99.17	99.17	105.97
Materials Research	110.87	118.87	118.87	139.07
Total MPS	473.04	502.76	502.76	547.00
Science and Technology Research Centers *Annualized	0.00	30.00*	30.00	60.00
Scientific, Technological and International Affairs				
Industrial Science and Technological Innovation	17.28	19.04	19.04	21.77
International Cooperative Scientific Activities	10.73	11.55	11.55	12.23
Policy Research and Analysis	0.85	0.85	0.85	0.85
Science Resources Studies	3.95	4.51	4.51	6.11
Research Initiation and Improvement	11.24	15.04	15.04	18.04
Total STIA	44.05	50.99	50.99	59.00
Program Development and Management	84.48	95.55	90.55	100.00
Total, Research and Related	1,454.23	1,633.01	1,628.01	1,842.00
U. S. ANTARCTIC PROGRAM				
U.S. Antarctic Research Program	13.50	15.50	15.50	17.50
Operations Support	85.40	92.20	87.20	95.20
Major Construction and Procurement	25.90	33.30	28.30	33.30
Total USAP	124.80	141.00	131.00	146.00
SCIENCE AND ENGINEERING EDUCATION				
Teacher Preparation and Enhancement	45.52	53.50	63.50	69.50
Materials Development, Research, and Informal Science Education	37.54	43.50	44.00	55.00
Undergraduate Science, Engineering, and Mathematics Education	19.00	23.50	28.00	33.00
Research Career Development	34.00	31.00	31.00	38.00
S[illegible] and Program Assessment	3.20	4.50	4.50	4.50
Total SEE	139.26	156.00	171.00	200.00
TOTAL NSF	$1,718.23	$1,930.01	***	$2,188.00

*** No total provided. Column entries are CP for PD&M, SEE, and USAP; 1989 Request for all others.

Mr. **Nagle**. Let me thank you for coming, for your testimony again. It is good to see you again.

This hearing will stand adjourned.

Mr. **Bloch**. Thank you.

[Whereupon, at 12:22 p.m., the subcommittee recessed, to reconvene at the call of the Chair.]

APPENDIXES

APPENDIX I

ROBERT A. ROE, New Jersey, CHAIRMAN

GEORGE E. BROWN, Jr., California
JAMES H. SCHEUER, New York
MARILYN LLOYD, Tennessee
DOUG WALGREN, Pennsylvania
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TOM McMILLEN, Maryland
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DAVID R. NAGLE, Iowa
JIMMY HAYES, Louisiana
DAVID E. SKAGGS, Colorado
JERRY F. COSTELLO, Illinois
HARRY JOHNSTON, Florida
JOHN TANNER, Tennessee

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Executive Director
ROBERT C. KETCHAM
General Counsel
DAVID D. CLEMENT
Republican Staff Director

March 21, 1989

Mr. Erich Bloch
Director
National Science Foundation
1800 G Street, NW
Washington, D.C. 20550

Dear Mr. Bloch:

On behalf of the Subcommittee on Science, Research and Technology, thank you for your informative and forthright testimony on March 16, 1989 concerning NSF programs. During the hearing several members requested additional information. In order to complete the hearing record, we would appreciate receiving your responses to the following:

1. What is NSF's estimate, assuming no budgetary restrictions, for the optimum funding levels to achieve the maximum effectiveness in each of the major activities of the Science and Engineering Education Directorate (SEE)? Please indicate the time scale associated with achieving major goals in each activity, for example, for the in-service teacher training institutes, the number of teachers who would participate in a fixed period of time.

2. What were the budget request levels for each of NSF's programs that NSF originally sent to OMB for the FY 1990 budget?

3. In response to a question from Mr. Wolpe concerning the magnitude of the increase in the FY 1990 budget for SEE precollege programs relative to other SEE programs, you stated that the decision to increase the precollege programs by 8% took into consideration the precollege science and math efforts in the Department of Education. Can you please elaborate on the proposed Department of Education programs in precollege science and math education which overlap or complement the NSF programs?

Mr. Erich Bloch
March 21, 1989
Page 2

4. Please outline NSF's appellate review process for protests arising from the results of the merit review process.

5. Mr. Bruce Manheim of the Environmental Defense Fund testified before our Subcommittee that the NSF's Safety, Environment and Health Initiative in Antarctica fails to meet existing or proposed international standards for reducing pollution from research bases, preventing impacts to Antarctic wildlife and protected areas, and assessing and monitoring of environmental impacts. His testimony addressed eight different areas in which NSF's program was lacking. We would like to receive NSF's response to his testimony, addressing the NSF initiative in each of the eight areas he outlined.

6. What data are available for evaluating the success of NSF's programs for attracting women and minorities to careers in science and engineering? To what extent is NSF duplicating its successful model programs in other places?

I appreciate your attention to this request. Your reply will be included in the printed hearing record.

Sincerely,

Doug Walgren

DOUG WALGREN, Chairman
Subcommittee on Science,
Research and Technology

W/Wll

MAY 2 1989

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

OFFICE OF THE
DIRECTOR

April 27, 1989

Honorable Doug Walgren
Chairman
Subcommittee on Science, Research
and Technology
Committee on Science, Space,
and Technology
House of Representatives
Washington, DC 20515

Dear Mr. Walgren:

Thank you for the opportunity to testify on NSF programs and priorities on March 16. Enclosed please find responses to the questions you sent me on March 21. I hope you find this material to be informative. Should you desire any additional information, please do not hesitate to contact me.

Thank you again for the opportunity to appear before your Subcommittee to discuss our proposals for FY 1990.

Sincerely,

Erich Bloch
Director

Enclosure: Responses to questions from Science, Research and Technology Hearing.

cc: Honorable Sherwood Boehlert

QUESTIONS SUBMITTED TO MR. BLOCH FOR THE RECORD BY DOUG WALGREN NATIONAL SCIENCE FOUNDATION (NSF) AUTHORIZATION HEARING

March 16, 1989

Question: What is NSF's estimate, assuming no budgetary restrictions, for the optimum funding levels to achieve the maximum effectiveness in each of the major activities of the Science and Engineering Education Directorate (SEE)? Please indicate the time scale associated with achieving major goals in each activity, for example, for the in-service teacher training institutes, the number of teachers who would participate in a fixed period of time.

Answer: Assuming no budgetary restrictions, an annual funding level of about $600 million would be adequate for SEE activities. This amount would be divided among the major activities as follows - $300 million for precollege programs, $200 million for undergraduate activities, and $100 million for graduate-level support.

Precollege programming, based in part on the recommendations of the Congressionally-mandated SRI, International report, will achieve:

- curriculum development for precollege science and mathematics;
- in-service teacher institutes;
- pre-service teacher preparation;
- informal science education in the form of educational television and radio, museums, aquariums, and other non-school learning environments;
- effective use of advanced technology in education

Undergraduate programs, based in part on the 1986 National Science Board report and on the 1988 Undergraduate Planning Workshops, will support:

- instrumentation
- laboratory development
- faculty professional enhancement
- course & curriculum development
- comprehensive improvement projects
- undergraduate research participation
- minority institution programs to increase the participation of minorities in science, math, and engineering.

Graduate programming will achieve:

- doubling the number of NSF Graduate Fellows as provided in the Fellowship Management Plan;

- implementation of a NSF Traineeship Program.

Question: What were the budget request levels for each of NSF's programs that NSF originally sent to OMB for the FY 1990 budget?

Answer: The following table submitted to OMB displays the NSF budget request for FY 1990:

SUMMARY OF FY 1990 BUDGET BY APPROPRIATION

(Millions of Dollars)

Activity/Subactivity	FY 1988 Actual	FY 1989 Request	FY 1989 Current Plan	FY 1990 Request
RESEARCH AND RELATED ACTIVITIES				
Biology, Behavioral and Social Sciences				
Molecular Biosciences	$44.60	$48.34	$48.34	$54.42
Cellular Biosciences	54.24	57.60	57.60	61.86
Biotic Systems and Resources	50.04	65.29	65.29	78.92
Behavioral and Neural Sciences	43.78	46.50	46.50	49.73
Social and Economic Science	30.15	32.59	32.59	33.65
Instrumentation and Resources	34.15	38.42	38.42	43.42
Total BBS	265.96	288.74	288.74	322.00
Computer and Information Science and Engineering				
Computer and Computation Research	19.95	22.30	22.30	24.86
Information, Robotics and Intelligent Systems	17.81	19.85	19.85	22.41
Microelectronic Information Processing Systems	13.24	16.00	16.00	20.06
Advanced Scientific Computing	44.34	55.80	55.80	71.90
Networking and Communications Research and Infrastructure	11.55	17.68	17.68	27.27
Cross-Disciplinary Activities	17.03	17.50	17.50	21.50
Total CISE	123.92	149.13	149.13	188.00
Engineering				
Chemical, Biochemical, and Thermal Engineering	28.90	31.90	31.90	34.78
Mechanics, Structures, and Materials Engineering	25.78	29.05	29.05	31.01
Electrical, Communications, and Systems Engineering	23.38	25.28	25.28	28.12
Design, Manufacturing, and Computer-Integrated Engineering	15.39	17.67	17.67	20.01
Emerging Engineering Technologies	16.59	19.44	19.44	22.28
Critical Engineering Systems	25.11	28.26	28.26	30.10
Cross-Disciplinary Research	36.33	43.36	43.36	52.70
Total ENG	171.48	194.96	194.96	219.00
Geosciences				
Atmospheric Sciences	96.33	104.25	104.25	110.96
Earth Sciences	51.29	59.27	59.27	68.47
Ocean Sciences	135.38	146.52	146.52	154.23
Arctic Research Program	8.34	10.84	10.84	13.34
Total GEO	291.34	320.88	320.88	347.00
Mathematics and Physical Sciences				
Mathematical Sciences	63.67	67.97	67.97	73.27
Astronomical Sciences	86.02	90.04	90.04	94 54
Physics	118.21	126.71	126.71	134.15
Chemistry	94.27	99.17	99.17	105.97
Materials Research	110.87	118.87	118.87	139.07
Total MPS	473.04	502.76	502.76	547.00
Science and Technology Research Centers *Annualized	0.00	30.00*	30.00	60.00
Scientific, Technological and International Affairs				
Industrial Science and Technological Innovation	17.28	19.04	19.04	21.77
International Cooperative Scientific Activities	10.73	11.55	11.55	12.23
Policy Research and Analysis	0.85	0.85	0.85	0.85
Science Resources Studies	3.95	4.51	4.51	6.11
Research Initiation and Improvement	11.24	15.04	15.04	18.04
Total STIA	44.05	50.99	50.99	59.00
Program Development and Management	84.48	95.55	90.55	100.00
Total, Research and Related	1,454.23	1,633.01	1,628.01	1,842.00
U. S. ANTARCTIC PROGRAM				
U.S. Antarctic Research Program	13.50	15.50	15.50	17.50
Operations Support	85.40	92.20	87.20	95.20
Major Construction and Procurement	25.90	33.30	28.30	33.30
Total USAP	124.80	141.00	131.00	146.00
SCIENCE AND ENGINEERING EDUCATION				
Teacher Preparation and Enhancement	45.52	53.50	63.50	69.50
Materials Development, Research, and Informal Science Education	37.54	43.50	44.00	55.00
Undergraduate Science, Engineering, and Mathematics Education	19.00	23.50	28.00	33.00
Research Career Development	34.00	31.00	31.00	38.00
Studies and Program Assessment	3.20	4.50	4.50	4.50
Total SEE	139.26	156.00	171.00	200.00
TOTAL NSF	$1,718.29	$1,930.01	***	$2,188.00

*** No total provided. Column entries are CP for PD&M, SEE, and USAP; 1989 Request for all others.

Question: In response to a question from Mr. Wolpe concerning the magnitude of the increase in the FY 1990 budget for SEE precollege programs relative to other SEE programs, you stated that the decision to increase the precollege programs by 8% took into consideration the precollege science and math efforts in the Department of Education. Can you please elaborate on the proposed Department of Education programs in precollege science and math education which overlap or complement the NSF programs?

Answer: The primary source of Department of Education funding for science and math education at the precollege level is through the Eisenhower Act (ECIA Title II). The Department has requested $142 million for this program in FY 1990; $132.8 million would be direct grants to the states, and $9.2 million would be discretionary funds for national programs. In FY 1989 the Department plans to use $6 million of these discretionary funds to support "model secondary schools" and $3 million will be used for open competition among programs for teacher training or development.

The Department of Education supports several other programs which have precollege science and mathematics components, although the programs are not limited to nor earmarked for science and mathematics. These programs include:

Secretary's Fund for Innovation in Education...	$15.7M
Fund for the Improvement and Reform of Schools and Teaching........................	5.9M
Magnet School Assistance........................	114.6M

In addition, President Bush released his "Educational Excellence Act of 1989" on April 5, 1989, which proposed a number of new initiatives in the Department of Education directed at precollege education:

- Rewarding schools whose students demonstrate substantial educational progress;
- Recognizing superior teachers by establishing a President's Award for Excellence in Education;
- Establishing a National Science Scholars Program;
- Providing additional funding for magnet schools;
- Making grants to states and school districts to develop alternative certification systems;
- Making Drug Free Urban Emergency Grants to urban school systems with the most severe drug abuse problems.
- Expanding experimental programs in educational innovation and data collection;
- Endowing Historically Black Colleges and Universities;
- Improving accountability in education.

Question: Mr. Bruce Manheim of the Environmental Defense Fund testified before our Subcommittee that the NSF's Safety, Environment and Health Initiative in Antarctica fails to meet existing or proposed international standards for reducing pollution from research bases, preventing impacts to Antarctica wildlife and protected areas, and assessing and monitoring of environmental impacts. His testimony addressed eight different areas in which NSF's program was lacking. We would like to receive NSF's response to his testimony, addressing the NSF initiative in each of the eight areas he outlined.

Answer: The Environmental Defense Fund testimony contains a number of inaccuracies. For example, EDF's testimony charges that the waters off McMurdo Station are more heavily polluted in terms of PCB levels than virtually all estuaries and bays in the United States. This is not correct.

In fact, as environmental awareness in the United States and within the Antarctic Treaty System has increased, NSF has taken a number of steps to improve environmental practices at its antarctic stations.

- In the early 1980s at McMurdo Station, dumping of trash and scrap at the edge of Winter Quarters Bay was stopped and in recent years significant effort has been devoted to cleanup of that area and the station as a whole.
- In October, 1988 an announcement and summary, "Environmental Protection Agenda: U.S. Antarctic Program" was published in the Federal Register for comment. It covered the following topics:
    - planning for environmental management,
    - legal review of responsibilities,
    - environmental assessments and impact studies,
    - environmental awareness, and an
    - update of facilities and logistics plan with an emphasis on environmental consideration.
- Significant actions in Antarctica this past season, in addition to the Winter Quarter Bay clean up included:
    - cessation of ocean dumping,
    - extensive retrograde of metal scrap, old vehicles, construction material, batteries, tires, and other waste products to the U.S.;
    - general site cleanup facilitated by introduction of strategically placed dumpsters, and an
    - underwater survey and sampling of McMurdo's marine environs results of which are expected shortly.
- The FY 1990 Budget included $10 million for the first year of a five-year Safety, Environment and Health (SEH) initiative. Of this amount about $5 million is earmarked for environmental activities for which about $30 million is planned, mainly in the first three years of the initiative.

These funds will used for studies, procurement, construction, etc. related to the following topics:

- wastewater treatment and outfalls,
- solid waste minimization and disposition,
- incinerators,
- environmental monitoring, and
- other activities determined to be of high priority.

o The Foundations's Division of Polar Programs plans to hire shortly a Safety Environmental and Health Officer, who will have environmental oversight as a key responsibility.

o On February 7, 1989 the NSF Director and staff met with representatives of environmental groups concerning the environmental part of the SEH initiative and means for implementing it. There was unanimous support for the initiative, though some thought additional actions were needed too.

o During the next year, NSF will participate in the development of a new waste handling code for Consultative Parties to Antarctic Treaty, continue to work on pollution control at United States Stations, complete its review of NSF's compliance with environmental legal standards, and revise its Environmental Protection Agenda in response to what has been learned through these and other efforts.

Question: Please outline NSF's appellate review process for protests arising from the results of the merit review process.

Answer: Award of NSF assistance is discretionary. Nonetheless, it is the policy of the Foundation that an applicant whose proposal has been declined may receive an explanation and reconsideration.

A Principal Investigator (PI) whose proposal has been declined may obtain an explanation of the declination from the responsible Program Officer. If this explanation does not satisfy the PI that the proposal was fairly handled and reasonably evaluated, the PI may request reconsideration of the declination by the responsible Assistant Director. If the applicant institution is still not satisfied after reconsideration by the responsible Assistant Director, it may obtain further reconsideration by the Deputy Director of NSF. However, if a proposal has been declined after review by the National Science Board, only an explanation will be available.

Question: What data are available for evaluating the success of NSF's programs for attracting women and minorities to careers in science and engineering? To what extent is NSF duplicating its successful model programs in other places?

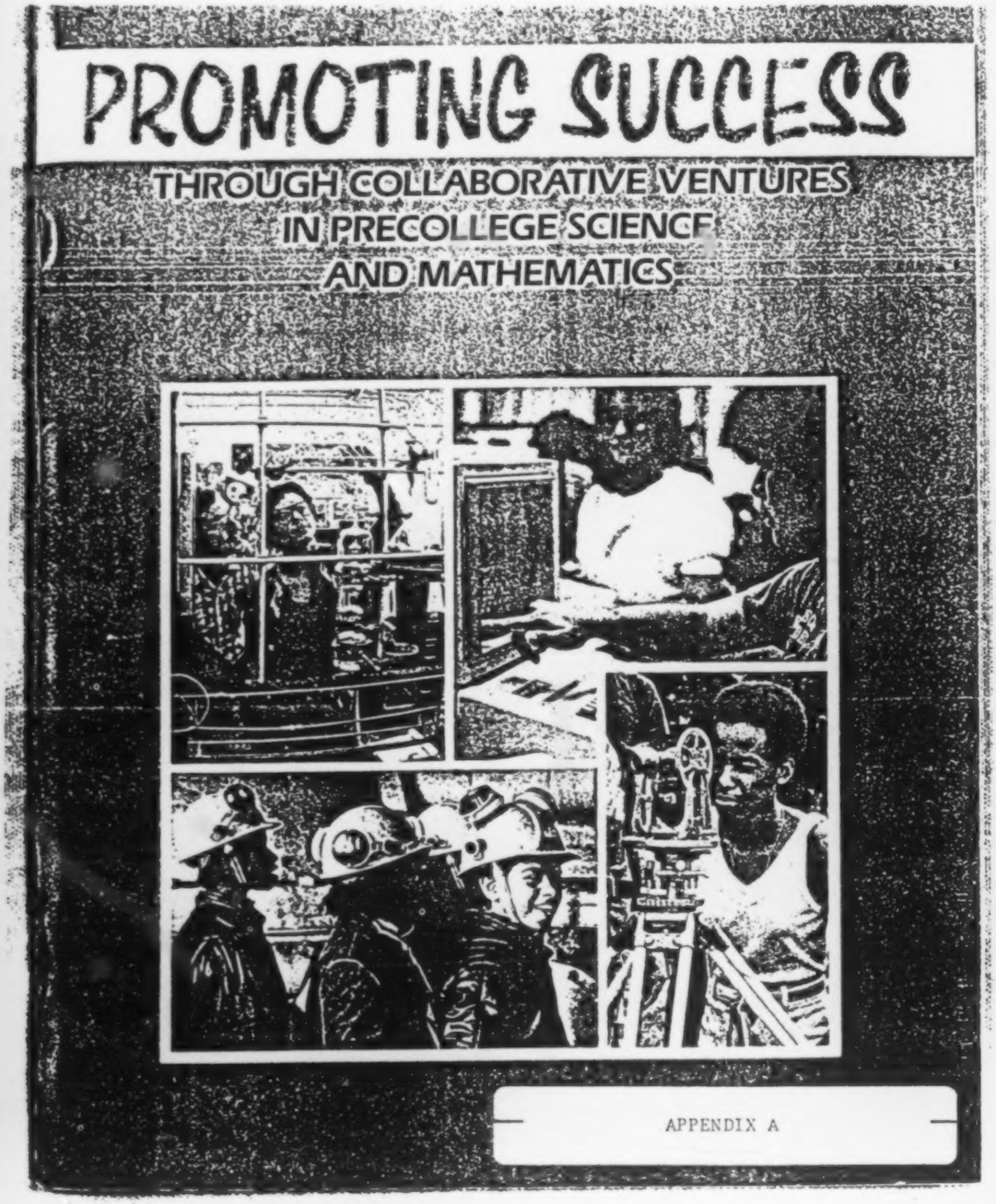
Answer: Data on the success of NSF-supported programs for attracting minorities and women into science and engineering careers are limited, but the quantitative data that are available indicate substantial success for a number of programs. For example, the attached table and graph from the NSF-supported National Association of Pre-College Directors (NAPD) shows that its member organizations (listed by acronym) have a very impressive record of sending their student participants on to college (82% to 4 year colleges) and into engineering (47%) and other math-based subjects (25%). All the member organizations are specificially involved in pre-college activities to prepare minority students to enter engineering or science programs in college.

The Young Scholars Program attempts to attract high ability and high potential students of all types to careers in science and engineering. Participation by women and minorities is strongly encouraged, and in 1988, the first year of the program, about 50% of the participants were women, and over 30% were minorities.

Since these students were at the time finishing grades 7-11, it is premature to determine the career impact of their experience. We are intensively collecting data about all participants, and plan in a few years to carry out a major evaluation of the program's effectiveness.

SEE/USEME's Comprehensive Regional Centers for Minorities projects each have formal evaluation components which include: internal formative evaluation feedback for ongoing quality control; two forms of outcome assessment involving data-based systems for out year tracking of students as they become adults entering careers; and national visiting committees to review and assess projects. However, since this program was initiated only in FY 1988, it will be a number of years before results affecting career selections are known.

In addition, NSF has recently put in place programs designed to attract women and minorities into the science and engineering pipeline. These efforts include the Research Careers for Minority Scholars, the Minority Research Centers of Excellence (which have a strong educational component) and the proposed women in engineering component of the Graduate Fellowship Program. NSF is placing greater emphasis on the Minority Graduate Fellowship Program increasing its participation from 10% of the total effort to 15% in FY 1990.



PROMOTING SUCCESS

THROUGH COLLABORATIVE VENTURES IN PRECOLLEGE SCIENCE AND MATHEMATICS

APPENDIX A

PROMOTING SUCCESS THROUGH COLLABORATIVE VENTURES IN PRECOLLEGE SCIENCE AND MATHEMATICS is a product of the National Association of Precollege Directors (NAPD), a coalition of nineteen precollege program directors whose mission and program efforts are directed at increasing the pool of minority students who pursue engineering and math based college study. Funding for the document was made possible through a grant from the Alfred P. Sloan Foundation supplemented with funds from the National Action Council for Minorities in Engineering (NACME).

TO ALL OUR STUDENTS WHO STRIVE FOR EXCELLENCE,
LABOR IN THEIR STUDIES AND SHARE THEIR
GIFTS OF LEARNING WITH OTHERS.

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No part of this document may be reproduced by any mechanical, photographic, or electronic process, or in the form of a phonographic recording, nor may it be stored in a retrieval system, transmitted, or otherwise copied for public or private use without written permission from the National Association of Precollege Directors (NAPD), c/o NACME 3 West 35 Street, New York, N.Y., 10001

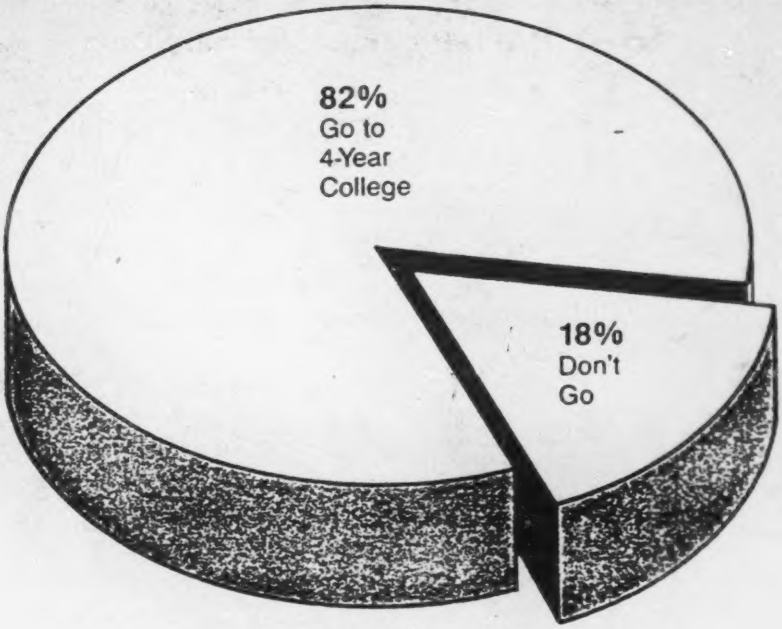
Table I. NAPD Program Summary Data

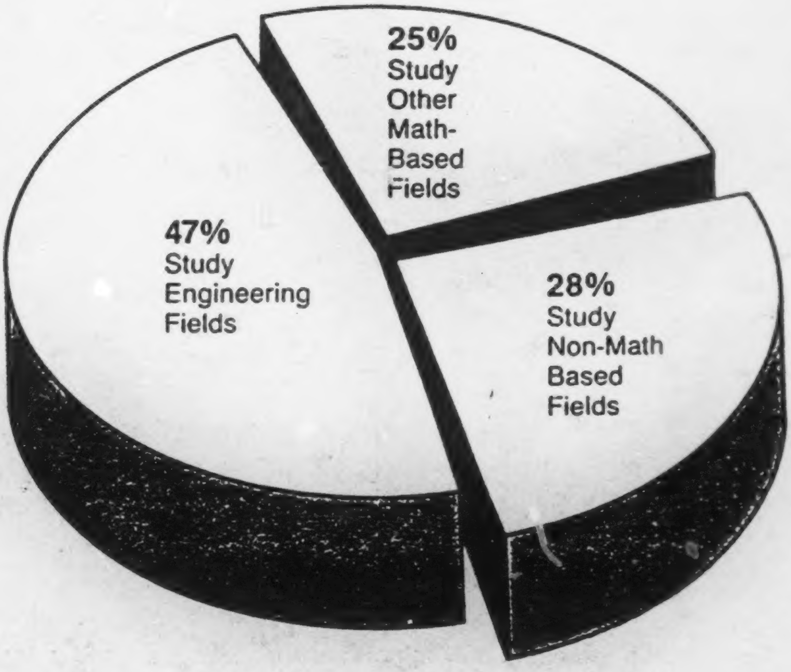
	1984 Precollege Participation		Year of First H.S. Graduates	High School Graduates Since Inception
	Students[a]	Schools		
BEAM	320	11	1983	33
CMEA	820	53	1983	84
CMSP	2,550	11	1975	1,650
DAPCEP	1,300	22	1981	503
FAME	250	b	1978	150
GEST	50	6	1977	150
IIT	450	b	1974	5,014
LEAP	238	8	1982	128
MASSPEP	300	6	1982	90
MESA/Cal.	3,820	138	1977	4,400
MESA/N.Mex.	310	10	1984	5
MESA/Wash.	2,200	11	1985	
METCON	981	13	1982	84
PRIME	1,866	33	1976	1,695
PRIS^{2}M	603	6	1980	257
SECME	9,211	160	1979	6,216
TAME	15,000	120	1979	4,000
UCMEP	500	4	1984	45

NOTES:

a. These figures represent only minority students who are full program participants. There are many additional minority and non-minority students who benefit from individual program elements but are not regular participants.

b. FAME and IIT both bring students from the schools to a central location for program activities.


82%
Go to
4-Year
College
18%
Don't
Go


25%
Study
Other
Math-
Based
Fields
47%
Study
Engineering
Fields
28%
Study
Non-Math
Based
Fields

1987 Update ATTACHMENT C

NATIONAL ASSOCIATION OF PRECOLLEGE DIRECTORS (NAPD)
COMPOSITE SURVEY OF PROGRAM ADMINISTRATION AND STUDENT DATA

The following survey data represent responses from the the 21 precollege programs whose staff constitute the membership of the National Association of Precollege Directors. The survey was conducted through a questionnaire that was sent to NAPD Program Directors in June 1987. The data indicated represent the NAPD Programs' best approximations of student enrollment and graduation from college.

INSTITUTIONAL AFFILIATIONS

1.) Number of Affiliated Universities 113

2.) Number of Affiliated Businesses 220

3.) Number of States Operating Program 35

4.) Number of Program Administrative Offices 45

STAFFING PATTERNS

5.) Number of Full Time Equivalent (FTE)Staff 96

6.) Number of Participant(1) College Faculty 175

7.) Number of Participant Business Loan Persons 30

8.) Number of Participant School Teachers 2,140

9.) Number of Employed(2) College Students 75

STUDENT DATA

10.) Number of Schools Operating Program 997

11.) Grade Levels Served 6-12

12.) Total Number of Students Enrolled in Program – 1986/87 37,850

13.) Number of Program Students at 4 Year Colleges 12,230

14.) Number and (%) of Program Students Enrolled In:

5,760 (47%) Engineering

6,470 (53%) Non-Engineering

15.) Est. Number of College Graduates 1985/86:

390 Engineering

423 Non-Engineering

16.) Est. Total Number of College Graduates Since Program Inception

2,930 Engineering

1,420 Non-Engineering

17.) Number and (%) of Students Participating in NAPD Programs That Have Won the 33 NACME Merit Scholarsip Awards Given in the Last 5 Years. 22 (67%)

P

DAVID PRICE
4TH DISTRICT
NORTH CAROLINA

COMMITTEES
BANKING, FINANCE AND URBAN AFFAIRS
SCIENCE, SPACE AND TECHNOLOGY
SMALL BUSINESS

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1777 CHAPEL HILL DURHAM BLVD.
SUITE 100
CHAPEL HILL, N.C. 27514
(919) [illegible]

SUITE 101
FEDERAL BUILDING
ASHEBORO, N.C. 27203
(919) [illegible]

CONGRESS OF THE UNITED STATES
HOUSE OF REPRESENTATIVES
WASHINGTON, D.C. 20515

May 1, 1989

Mr. Erich Bloch
Director
National Science Foundation
1800 G. Street, NW
Washington, D.C. 20550

Dear Mr. Bloch:

I am writing to thank you for your testimony before the Subcommittee on Science, Research and Technology in March. Even though I found your testimony quite interesting, and helpful to the Committee, some important differences apparently remain. I would like to take this opportunity to reiterate some of my concerns.

One of these is the NSF's funding for the social and behavioral sciences. I am dismayed over the apparent low regard in which these disciplines are held at the NSF and the fact that they have not enjoyed funding increases proportional to the rest of the Foundation. Even though the NSF-commissioned report Behavioral and Social Sciences: Achievements and Opportunities called for an increasing commitment to research and education within the social sciences, financial support for these disciplines languishes and it appears the Foundation has done little to implement the report's recommendations. I remain unconvinced by the figures you cited before the committee as evidence of substantial funding increases since you used 1982 --- a year of draconian cuts --- as your baseline. In fact, all subsequent increases have served merely to return social science funding to pre-1982 levels. I believe we must face this fact and do what we can to bring current increases in the social science budget up to the levels of other programs in NSF.

I am also concerned with the Foundation's reluctance to establish a separate directorate for the social sciences and the near-absence of social scientists from higher level positions in the NSF. With the exception of John Moore, who as deputy director for the entire Foundation cannot serve as an advocate for the social sciences, there are no social scientists in the upper reaches of your administration. Given what we know of organizational behavior, I believe that creating a separate directorate and/or appointing more social scientists to existing administrative posts would aid these disciplines in securing a more equitable share of the budget and make them a full partner within the NSF.

I urge you to give these suggestions careful consideration and hope you will not hesitate to call upon me should you wish to discuss them in greater detail.

Sincerely,

David Price

DAVID PRICE
Member of Congress

DEP/lmo

NATIONAL SCIENCE FOUNDATION
WASHINGTON D C 20550

nsf

OFFICE OF THE
DIRECTOR

June 6, 1989

Honorable David Price
House of Representatives
Washington, D.C. 20515

Dear Mr. Price:

Thank you for your letter of May 1, 1989. While I am glad you think my testimony was helpful, I do want to address your concerns regarding funding for the social and behavioral sciences.

First, with respect to the report, Behavioral and Social Sciences: Achievements and Opportunities, I was frankly disappointed because while it has many recommendations, they did not help us in the difficult job of priority setting. In fact, the report is presented as illustrative of opportunities. While I understand the difficulties of the task, I continue to be disappointed that some disciplines, including the behavioral and social sciences, are not coming to grips with this essential challenge of setting their own priorities. Certainly the report concludes that more resources are needed for the social and behavioral sciences, but in four years as Director of NSF I have not run across a scientific discipline that did not justifiably advance the same view.

Nonetheless, the report has had an impact in that several of the illustrative topics discussed are being supported or otherwise have had special attention. For example, awards have been made across several disciplines for research on job segregation and the wage gap between men and women; an effort is underway to stimulate use of supercomputers to develop a new generation of forecasting and policy analysis tools; and greater support is being provided for social and behavioral science instrumentation within the Division of Instrumentation and Resources. Also, it should be noted that other events have overtaken the findings of the report, such as establishment of the National Center for Geographic Information and Analysis and the need to understand the human dimensions of global change. This latter topic is emerging as a unique opportunity and responsibility for NSF to ensure that social and behavioral factors are considered in the science addressed to this major concern.

As you know, we proposed to emphasize the human dimensions of global change in our FY 1990 budget. However, because of the rapidly developing interest in this area, the Division of Social and Economic Science organized a solicitation for proposals for this fiscal year open to all areas of social science. The proposals received in response to this solicitation are being reviewed by a multi-disciplinary panel this month. The human dimensions of global change will continue to be an important part of our total planning in support of U.S. science related to global change.

Secondly, I chose 1982 as a year from which to make budget comparisons deliberately because (a) it was the low point of the funding for the behavioral and social sciences, and (b) it also is the beginning of the turn around for funding of the Foundation's budget.

Even with this expansion in funding for the National Science Foundation, the resources are limited and the priorities are many. The statistics I cited, however, reflect on a relative basis to biology and the rest of the Foundation the fact that we have addressed the cuts in the behavioral and social sciences in an aggressive way. There is no reason to assume that any discipline must always increase in funding or that prior levels of funding reflect the priorities of today. Rather than focusing on the level of funding of an individual discipline, the bottom line for the Foundation needs to be increased, as I have pointed out in my testimony over and over again, and through that action all disciplines are helped.

Thirdly, I disagree that a separate directorate for the social and behavioral sciences is what is required. I must say, in general, that the organization of an agency or department should be left to the determination of those that are responsible for its day to day operations and not be dictated by either Congress or a community with its own narrow self-interests. On a more specific basis, let me give you the reasons why I am opposing a separate directorate. I am for a streamlined organization that has fewer and not more stand alone entities for the sake of efficiency as well as for the fact that short communication lines can be maintained. That applies to the social sciences and many other disciplines.

Further, organizational changes usually do not correct problems, either real ones or problems of perception, and I strongly believe that the social and behavioral sciences should not be isolated either organizationally or intellectually. They have too many interfaces with other sciences and engineering that represent real opportunities for scientific advances. It is through this interplay that the social and behavioral sciences can gain the recognition that they so amply deserve.

I am sure that we will continue discussion of these topics. I do want you to understand that I am as much a champion of the behavioral and social sciences as I am of any of the other disciplines for which NSF is responsible. To suggest otherwise does not reflect the facts.

Sincerely,

Erich Bloch
Director

APPENDIX II

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE,
AND TECHNOLOGY
SUITE 2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515
(202) 225-6371

March 28, 1989

The Hon. Betty Castor
Commissioner of Education
Department of Education
The Capitol PL08
Tallahassee, FL 32399

Dear Ms. Castor:

On behalf of the Subcommittee on Science, Research and Technology, I would like to express our appreciation for providing us with the benefit of your experience and insight regarding science education in the public schools.

In your testimony at our recent hearing, you mentioned that the key to successful implementation of new science or mathematics textbooks is ensuring their adoption on approved textbook lists in the several large states, such as Florida, which have established these lists. In order to augment our hearing record on this important point, we would appreciate your providing a description of how the process for textbook adoption works along with any comments you might have on how NSF could improve the chances of new curricular materials being adopted. We will include this information in the printed hearing record.

Again, thank you for your willingness to be a resource to the Subcommittee. We know you share our goal of improving the standard for science and mathematics instruction in our Nation's schools.

Sincerely,

Doug Walgren

DOUG WALGREN, Chairman
Subcommittee on Science,
Research and Technology

DW/WII

FLORIDA DEPARTMENT OF EDUCATION
Betty Castor
Commissioner of Education

JUN 1 1989

May 11, 1989

Honorable Doug Walgren, Chairman
Subcommittee on Science, Research and Technology
United States House of Representatives
Suite 2321, Rayburn House Office Building
Washington, D. C. 20515

Dear Representative Walgren:

Thank you for your letter requesting a description of Florida's process for textbook adoption and for comments on how the NSF could improve the chances of new curricular materials being adopted.

A brief description of Florida's instructional materials adoption program is enclosed. As noted in the description, the various instructional materials councils adopt course specifications and criteria statements for the evaluation and selection of materials. These are then provided to interested publishers who in turn use them to decide if their materials are appropriate. If appropriate, the materials are then submitted for consideration by the various councils. Course specifications require that the materials submitted for adoption consideration address course content as contained in appropriate curriculum frameworks, describe the desired presentation of the content, specify the kinds of related materials desired, and designate the grade level for which the materials are to be designed.

The Florida Department of Education would welcome the opportunity to receive current information from the NSF regarding developments in math, science and computer education so that the instructional materials councils could be made aware of technological advances, curriculum needs, the results of assessment efforts and successful innovative pilot programs. This information would then be used to develop a "state-of-the-art" document to be used by instructional materials councils as they develop course specifications.

The Capitol • Tallahassee, Florida 32399 • (904) 487-1785

Affirmative action/equal opportunity employer

Honorable Doug Walgren
Page two
May 11, 1989

Since it takes a minimum of three years to develop and field test new textbooks, publishers should promptly be provided with the same information. It should be remembered that publishers respond to the demands of the marketplace. They will respond to the requirements of the states, especially when several of the larger states begin to ask for similar products.

Thank you for the opportunity to share my concerns and suggestions with the subcommittee. Please call on me if I may provide additional information or suggestions.

Sincerely,

Betty Castor

Betty Castor
Commissioner

BC/jtw

Enclosure

Copy: Donald S. Van Fleet
Laurey Stryker

State of Florida
Department of Education
Tallahassee, Florida
Betty Castor, Commissioner
Affirmative action/equal opportunity employer

FLORIDA'S INSTRUCTIONAL MATERIALS ADOPTION PROGRAM

FLORIDA DEPARTMENT OF EDUCATION

DIVISION OF PUBLIC SCHOOLS
BUREAU OF ELEMENTARY AND SECONDARY EDUCATION
INSTRUCTIONAL SUPPORT SERVICES

NOVEMBER 1988

FLORIDA'S INSTRUCTIONAL MATERIALS ADOPTION PROGRAM

The State of Florida has an extensive state-adoption process involving the submission of instructional materials by publishers for review by state and district instructional materials councils prior to recommendation for approval by the State Board of Education.

The decision as to which subject areas are to be included in each year's adoption is based on contract expirations as well as identified needs expressed by districts for new subjects and courses to be added to the state-adopted list. After the specific subjects and courses have been determined for an adoption, the Commissioner of Education appoints persons to serve on the various state instructional materials councils. The appointees are selected from nominations received from district superintendents, professional and educational associations, and individuals.

Following the appointment of the councils, a training and organizational meeting is called by the Commissioner of Education. The various councils meet in joint and individual sessions, as appropriate, to receive specific training in the evaluation of instructional materials; to establish and adopt policies and procedures for both state and district instructional materials councils; to develop and adopt course specifications and criteria statements for the evaluation and selection of materials; and to establish and adopt guidelines for publishers to follow in reporting the use of the Learner-Verification and Revision Process.

Shortly after the organizational meeting, the Department mails a notice to all publishers on a perpetual mailing list advising them of the upcoming adoption and outlining details for submitting bids. Publishers have until June 15 to submit their bids.

About the same time, the Department extends a written invitation to the school districts to participate in the pre-adoption evaluation of the instructional materials to be considered for adoption.

After all bids have been received from publishers, a list of the materials to be evaluated in each subject and/or course is compiled. The list, accompanied by other necessary information, forms, etc., is sent to individual members of the state councils and to the coordinators of the district councils.

To aid districts in establishing and training evaluation councils and in carrying out their responsibilities, the Department conducts an annual workshop. Two or three representatives from each participating district are invited to attend. These representatives are then expected to assist their local district councils. In addition, members of district instructional materials councils receive training in the selection of instructional materials through district summer inservice institutes or some other inservice vehicle. The training program is based on a formal program developed by the Department of Education.

Publishers furnish evaluation samples and pertinent written information regarding their materials to individual members of the state councils and to the district councils. The deadline for shipping the samples is established by the state councils and is usually July 15.

When district evaluations are received by the Department, they are compiled into a computerized report to be submitted to the appropriate state councils. The report includes each district council's evaluation, ranking, comments, and recommendations for each submission. Evaluations from professional organizations may be included in the report, also.

The state councils meet individually in Tallahassee during the fall and early winter months to determine which, if any, of the materials submitted to recommend for adoption. In reaching that decision, the following are taken into consideration: (1) the publishers' compliance with all legal requirements; (2) the district councils' evaluations; (3) the publishers' presentations; (4) written and/or oral evaluations and recommendations from individuals and special interest groups; (5) individual council members' evaluations; and (6) council discussion about each submission. The councils' policies require a two-thirds vote of members present to recommend a submission for adoption.

When all state councils have met and made their recommendations, a single report is prepared and forwarded to the Commissioner of Education. The Commissioner, in turn, submits the report to the State Board of Education, along with her recommendations regarding it. The Board makes the final decision as to which of the recommended materials are adopted. At the present time, materials are placed on four-to-six-year contracts beginning on April 1 of the year in which they are adopted. At the end of the third year of the contract, publishers have the option of increasing their prices in accord with limitations set forth in Section 233.17, Florida Statutes. With the agreement of the publishers, contracts may be extended for one or two years.

Following action by the Board, the Department notifies the school districts that new materials have been adopted and furnishes them with a list of the specified titles, prices, etc. Purchasing may begin on April 1.

Being on the state-adopted list does not ensure that materials will be selected and purchased by the schools. Each district has responsibility for evaluating, selecting, and purchasing specific materials to be used in its classrooms. Districts vary in their policies and procedures for selecting materials. Some districts have single basal adoptions; some have multiple basal adoptions; and others permit their schools to select from the entire state-adopted list. In some districts, evaluations and selections are made at the district level, while in others the decisions are made at the school level. State law does, however, require that materials must be evaluated before they are used for the first time by a district. In addition to selecting from the state-adopted list, districts may use up to fifty percent of their state categorical funds to purchase materials not on the state list.

Appendix III

ADELAIDE • AMSTERDAM • ANCHORAGE • AUCKLAND • BOSTON • BRUSSELS • BUENOS AIRES • CHICAGO • COPENHAGEN • DUBLIN
FORT LAUDERDALE • GOTHENBERG • HAMBURG • LEWES — U.K. • LONDON • LUXEMBOURG • MADRID • MONTREAL • OSLO • PALMA DE MALLORCA
PARIS • ROME • SAN FRANCISCO • SAN JOSE — COSTA RICA • SEATTLE • STOCKHOLM • SYDNEY • TORONTO • VANCOUVER • VIENNA
WASHINGTON • WORLD PARK BASE — ANTARCTICA • ZURICH

GREENPEACE

Greenpeace USA • 1436 U Street NW • Washington DC 20009 • Tel (202) 462-1177
Tlx 89-2359 • Fax (202) 462-4507

The following is the statement of Greenpeace USA to the Subcommittee on Science, Technology and Research of the United States House of Representatives. The statement addresses generally the U. S. Antarctica Program under the National Science Foundation, and specifically the environmental aspects of the proposed Safety, Environment and Health Initiative.

Susan Sabella, U.S. Antarctica Campaign Coordinator

Greenpeace is an international environmental organization with over 1.2 million supporters in the United States. The organization has been active in Antarctic issues for several years, campaigning to have the continent protected as a World Park. Since the austral summer of 1985/86, Greenpeace has visited the Antarctic each year, expanding our monitoring of human presence on the fragile Antarctic environment. During the 1986/87 season, we established a small, minimum-impact, year-round station on Ross Island. Since then, Greenpeace expeditions have conducted environmental monitoring and documented waste disposal practices at 22 stations belonging to 16 nations.

Greenpeace inspections have revealed that most scientific stations and support operations are seriously damaging the environment, and do not meet environmental standards established under the Antarctic Treaty. Visits to U.S. stations, Palmer and McMurdo, have confirmed that the U.S. policy and practices for disposal of waste do not comply with Treaty recommendations, including the Code of Conduct and the Agreed Measures for the Conservation of Antarctic Fauna and Flora. Both stations discharge raw sewage into the surrounding waters. McMurdo station operates a land fill and burns its combustible waste, including toxic materials, in open pits. Both open incineration and the dumping of untreated sewage are prohibited in the United States. Furthermore, mountains of scrap metal and defunct machinery, dating back to the program's earliest days, have been left behind by previous U.S. operations. Some of this rubbish has been in the Antarctic for as long as thirty years. More than merely unattractive, this trash has contributed heavily to the contamination of the McMurdo Sound.

The Antarctic is the last great wilderness on earth, and home to rare plant and animal species including, penguins, seals, and whales. Base activities and irresponsible waste disposal operations can significantly alter and even destroy the fragile marine environment as well as the small amount of ice-free land available to sustain the continent's wildlife. In addition, scientists now know that the Antarctic plays a critical role in

RECYCLED PAPER

regulating climatological change. The continent provides a unique laboratory in which to study such phenomena as stratospheric ozone depletion and the greenhouse effect. The value of this continent as a pristine wilderness and global laboratory must not be threatened by the continued introduction of local contaminants.

The National Science Foundation has repeatedly stated that it lacks the funding necessary to address the environmental impacts of its Antarctic operations, and that to do so would be at the expense of scientific research. Therefore, in order to avoid further tradeoffs between the environment and science, Greenpeace believes that Congress should appropriate the FY 1990 $10 million special fund requested by the NSF for environmental, health, and safety purposes. This special funding must continue as long as necessary. Furthermore, Greenpeace urges the Congress to take an active role in ensuring that the National Science Foundation takes all necessary steps to swiftly and significantly decrease the U.S. Antarctic Program's environmental impacts. The successful implementation of a truly sound environmental initiative and clean up effort by the U.S. would set an example for other Treaty nations to follow.

While Greenpeace is in favor of the National Science Foundation receiving additional resources to undertake an environmental initiative, increased funding is not the total solution. The NSF must devise a comprehensive plan that will fully implement the Antarctic Conservation Act, eliminate the sources of land, air and water pollution within their operations, and ensure full compliance with all applicable U.S. and international environmental laws. Greenpeace is not satisfied that the proposed initiative will achieve these goals.

With regard to wastewater disposal, the initiative suggests submerging the outfalls and installing macerators at both Palmer and McMurdo bases. While these measures may indeed aid in dispersing the waste, they do nothing to address the actual contents of these effluents. A chemical analysis of McMurdo's outfall performed by Greenpeace scientists identified elevated levels of heavy metals in the effluent. These metals, lead, cadmium, zinc, copper, and silver, are toxic and can have serious effects for the local marine environment. The proposed actions also do nothing to reduce the biological oxygen demand (BOD) of the effluent. Indeed, maceration may increase BOD. It is essential for the Foundation to locate the sources of the heavy metals contamination and install equipment such as rotators and filters to reduce BOD.

Concerning disposal of solid wastes, the initiative actually proposes very little. Recommendations include minimizing use of plastics, investigating the possibility of installing an incinerator at McMurdo, and filling in the Winter Quarters Bay dump. Other than restricting the use of plastics, these proposals do not amount to much in terms of improving environmental standards of U.S. Antarctic operations. Furthermore, the initiative fails to address McMurdo's Fortress Rock landfill. This method of solid waste 'disposal' is wholely incompatible with the protection of the Antarctic environment and must be terminated.

An obvious source of land pollution, McMurdo's Fortress Rock landfill receives at least 500 tons of combustible trash annually, including packaging materials, paper, tin and aluminum cans and plastics. In addition, the dump receives a variety of non-combustible materials including scrap metal and old machinery. The non-combustibles, plus whatever combustible wastes aren't totally consumed in the burn, are bulldozed under and covered with soil. This practice of landfilling will make it almost impossible to remove this waste in the future.

Landfills also contribute significantly to the contamination of surface and ground water. At McMurdo, run-off from nearby snowfields drain through the landfill, coming in contact with incineration ash. The leachate flowing from the landfill then transports contaminants to other areas of the station. Much of the run-off eventually ends up in McMurdo Sound.

It should be noted that McMurdo's Fortress Rock landfill complies with neither international nor domestic regulations. Fortress Rock does not meet landfill standards set by the U.S. Environmental Protection Agency. The Code of Conduct prohibits coastal stations from operating landfills altogether.

Although the initiative ignores the environmental impacts of the Fortress Rock landfill, it acknowledges the need to phase out the open burning of the dump. To do so, the initiative states that the NSF will study the possibility of installing an incinerator at Fortress Rock. However, it must be pointed out that the Safety Panel report, upon which the initiative is based, suggests either installing an incinerator or retrograding combustible wastes as possible alternatives to open incineration. It is unacceptable that the NSF has chosen to disregard the panel's recommendation to retrograde combustible wastes. Indeed, nowhere in the initiative is the option of retrograding combustible materials even mentioned. From an environmental protection perspective, the best alternative is to remove the wastes from the continent.

Greenpeace Toxics Division has done extensive research into the environmental impacts of incinerators and has concluded that incineration, whether in a state-of-the-art incinerator or in open pits is not appropriate technology for the fragile Antarctic. Incinerator ash and emissions are sources of polychlorinated dioxins, and furans - two groups of chemicals that include the most toxic substances known to science. Many modern products, ordinary cleaning products, newspapers, cans, personal care products and plastic packaging, contain numerous toxic substances, ranging from heavy metals in inks and cans to dioxins in paper. When the refuse is burned, volatilized metals and organic chemicals are released into the air and concentrated in the ash. The U. S. Environmental Protection Agency's "National Dioxin Study" has pinpointed refuse incinerators as major sources of dioxin and furans.

It is for these reasons that Greenpeace calls for an end to landfill/open incineration operations and does not support the installation of an incinerator at McMurdo or other U.S. facilities.

One dumpsite that the initiative does address is the former dump at Winter Quarters Bay. The Winter Quarters Bay dump is the result of decades of discarding all manner of solid waste onto the annual ice in McMurdo Sound. This mountain of metal and trash accumulated at the shoreline has contributed greatly to the destruction of the marine environment of Winter Quarters Bay. The initiative states that the best way to deal with the Winter Quarters Bay dump is to "landscape" the area by encasing the mass of waste under a layer of soil. While improving the site aesthetically, burial does nothing to address environmental impacts. On the contrary, burial ensures that the waste will remain in Antarctica forever. Furthermore, there is no guarantee that the wastes, once capped, will not continue to contaminate the water and sediment of McMurdo Sound. Greenpeace believes the more appropriate measure would be to monitor the dump and continue to remove the waste.

The successful implementation of the above recommendations will rest heavily on increased environmental awareness among NSF, Navy and contracted employees, strict enforcement of regulations, and a comprehensive environmental monitoring program. The NSF's Draft Environmental Protection Agenda thoroughly outlines what is needed in terms of environmental education. The Foundation is presently conducting a search for a Safety, Environment and Health Officer to initiate, oversee, and enforce the initiative's new measures. What seems to be missing is the commitment to develop an environmental monitoring program.

A comprehensive monitoring program that includes on-going sampling and analysis of soil, sediments, effluent, leachates and exhaust emissions must be instituted immediately. Without accurate and regular monitoring, problem areas cannot be identified or remedied. Most certainly, without environmental monitoring, the Foundation cannot, in any meaningful way, determine whether or not their operations are having a negative impact on the environment. For example, an accurate and regular sampling program would have alerted Foundation officials to the metals contamination of McMurdo's effluent.

The above comments point out a number of areas where the NSF's environmental initiative falls drastically short of adequately improving environmental protection at U.S. stations. Greenpeace urges the Foundation to reassess its proposal, and consider the points raised here. Additionally, more information regarding the initiative's priorities, the nuts and bolts of implementation and time-frame for the projects must be made available to the Congress and the public as soon as possible. Greenpeace considers cleanup of the U.S. installations in Antarctica to be of the utmost urgency. We respectfully request that Congress provide the funding and the oversight to guarantee that this cleanup effort proceeds in the most expedient and thorough manner possible.

RHODE ISLAND
COLLEGE

Department of Mathematics and
Computer Science

March 6, 1989

Representative Sherwood Boehlert
Congress of the United States
House of Representatives
Washington, D.C. 20515

Dear Representative Boehlert,

Thank you for allowing me the opportunity to present my written testimony concerning the actions needed to improve mathematics education in our nation. I have taught college mathematics, trained preservice undergraduate and graduate mathematics students for the past fifteen years. For the past three years, I have been the Director of the Excellence in Teaching Mathematics Project for the state of Rhode Island; this project develops mathematics inservice training programs for grades kindergarten through twelve. Based on these experiences, I recommend your attention be focused on preservice teachers, first year teachers, inservice training, public awareness, National Science Foundation grants, and conferences.

Providing programs for preservice teachers is addressed by H.R. 996, and BOEHLE028. The bills represent a positive initiative to get students involved in the field of mathematics teaching but does not necessarily attract the best and the brightest students. The pool of applicants should not be limited to women and minorities but to the best and the brightest of our nation's youth. It is imperative that we attract students that are excellent mathematicians to become the future mathematics educators that our country desparately needs. The programs proposed represent a positive response to the need for "good" mathematics students who could not otherwise afford a college education. The selection of these future mathematics teachers should be made with the assistance of the local mathematics teacher association. I agree that academic merit should be an important criteria for selection, however, a commitment and affinity toward teaching needs to be included.

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Department of Mathematics and
Computer Science

A program for first year teachers needs to be designed. A crucial step to succeeding in schools is surviving the first year of teaching. Many first year teachers are given five preparations, the lowest level classes and the least motivated and motivating classes. This situation becomes emotionally difficult for these new teachers. There are an increasing number of first year teachers that are "dropping out" of teaching during their first year. Ideally, first year teachers should have only three preparations in which one preparation includes an upper track class; they need an in-school mentor or master teacher that will provide them with the guidance and support for lesson planning, disciplining, adjusting to teaching, and dealing with the various social issues involved in educating our youth. By providing these new teachers with a mentor to act as guide, the new teacher does not have to "re-invent the wheel" and can concentrate on innovative teaching.

An inservice training program that emphasizes classroom support by a teacher resource agent or master teacher is necessary for new teaching methodology to be implemented. A skill bank of innovative teachers is needed to assist the teacher in class to implement and explore new teaching methods. Inservice training is needed to train teachers to provide active learning environments for students. The teacher's role then will become a consultant and facilitator of learning not just a presentor and authority of knowledge. The active learning approach which may involve group work, the use of manipulative aids, or computer labs require experienced teachers in these methods to assist novice teachers. By working directly with the teacher in the classroom, one can demonstrate how to implement this type of teaching methodology

There needs to be a public awareness of the importance of mathematics through libraries, museums, displays, parent and teacher inservice, shopping malls, and other public locations.

Although the National Science Foundation has a solicitation on Teacher Enhancement, at present one needs to be a professional grant writer to attain these funds. The current process is too time consuming for a

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"good" teacher since administrative support is lacking. Teachers with good ideas need support and direction with writing and developing a proposal. The preliminary proposal does not bridge this gap. The National Science Foundation needs to make this process easier. A suggestion would be to create a software program to facilitate the proposal writing process.

Other areas that need attention include the involvement of other groups that can affect change in schools: parents, principals, counselors, and industry. NSF should focus attention to funding that supports conferences that bring these groups together to discuss their role in the improvement of mathematics education.

I am pleased that Congress is taking a pro-active stance toward mathematics education. We, collectively, as a nation need to strive for Excellence in Teaching Mathematics. The House has made a formidable effort toward this goal and should exert its influence to ensure that our students get the best training in mathematics so that they can compete in our technological society.

Sincerely,

Vivian R. Morgan
Vivian R. Morgan

Director of the Excellence in Teaching Mathematics Project
Assistant Professor of Mathematics

Providence, Rhode Island 02908
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ASSOCIATION OF UNIVERSITIES FOR RESEARCH IN ASTRONOMY, INC.

SUITE 701
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WASHINGTON, D.C. 20036
202-483-2101

Goetz K. Oertel
President

March 14, 1989

Chairman Doug Walgren
2241 Rayburn House Office Building
Washington, D.C. 20515-3818

Dear Mr. Chairman:

I am responding to a request from the committee's staff to submit supplementary information for the March 14, 1989 hearing on astronomy support by the National Science Foundation (NSF).

By the middle of this century a few private US institutions had built the world's premier telescopes. An elite of astronomers from around the world had joined these organizations and was using the telescopes. With the entire universe to study and few premier telescopes available, little observing time was left for astronomers at other institutions.

In 1960, the Association of Universities for Research in Astronomy (AURA), a non-profit corporation, was formed to promote astronomy and to establish national observatories to which any astronomer with a good idea could come and use world class telescopes regardless of his or her institutional affiliation. Today AURA includes twenty premier US universities and operates the National Optical Astronomy Observatories (NOAO) with sites in Arizona, New Mexico, and Chile for the NSF, and the Space Telescope Science Institute in Baltimore, Maryland for NASA. Guided by its Board of Directors, AURA oversees these national centers and brings a university perspective to bear on their operation. AURA and its Directors are trustees and advocates for the centers' missions. The Chairman of the Board is Dr. Robert Noyes, Professor at Harvard University, and the Vice Chairman is Mr. Harry Albers, General Manager of San Diego State University.

NOAO and its groundbased observatories, like other national and university-based observatories which depend upon NSF funding, have experienced sharply declining budgets (enclosure 1) even as the mission and the quantity and quality of demand for facilities have increased. Through austerity, NOAO has kept its doors open; and through ingenuity it has maintained leadership (enclosure 2). It has developed a visionary yet realistic plan for its future (enclosure 3). Yet, it is now so underfunded that even small further reductions in its budget would cause telescopes to be closed (enclosure 4).

Enclosures 5-10 provide material which demonstrates the value of astronomy for science, technology, and education (5), and which indicates that this value is recognized and shared by many Americans (6). There are also comments on the relationship between groundbased and space astronomy (7) and on a comparison of US and European groundbased astronomy programs (8).

"America ignores astronomy at its peril" said Judge Wildenthal in an editorial in the Houston Chronicle earlier this year! Indeed, funding for groundbased astronomy is not commensurate with its outstanding merits for science, technology, and culture. It now needs a strong restoration program at the NSF.

AURA appreciates this opportunity to assist the committee in its evaluation of NSF astronomy and urges the committee to endorse NSF's support for research in the physical sciences.

Very sincerely yours,

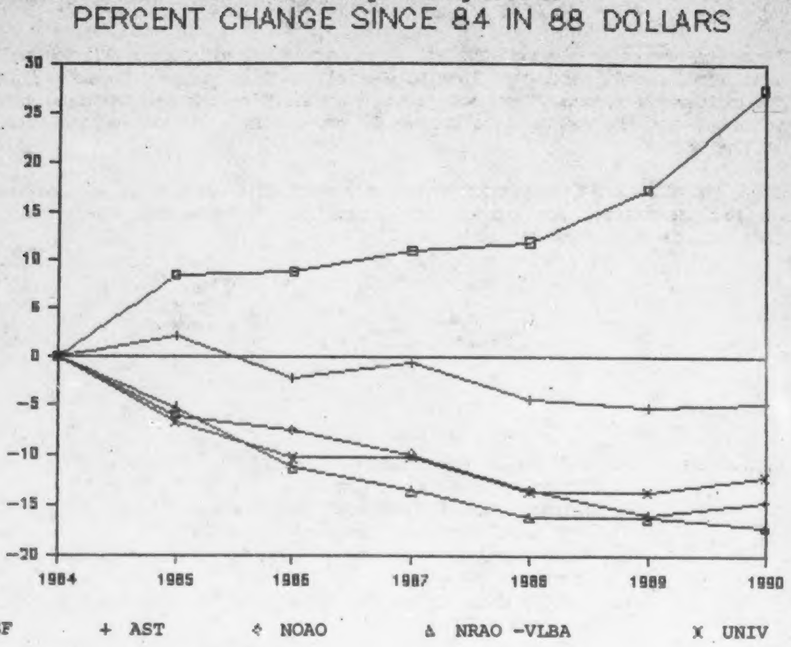
Goetz Oertel

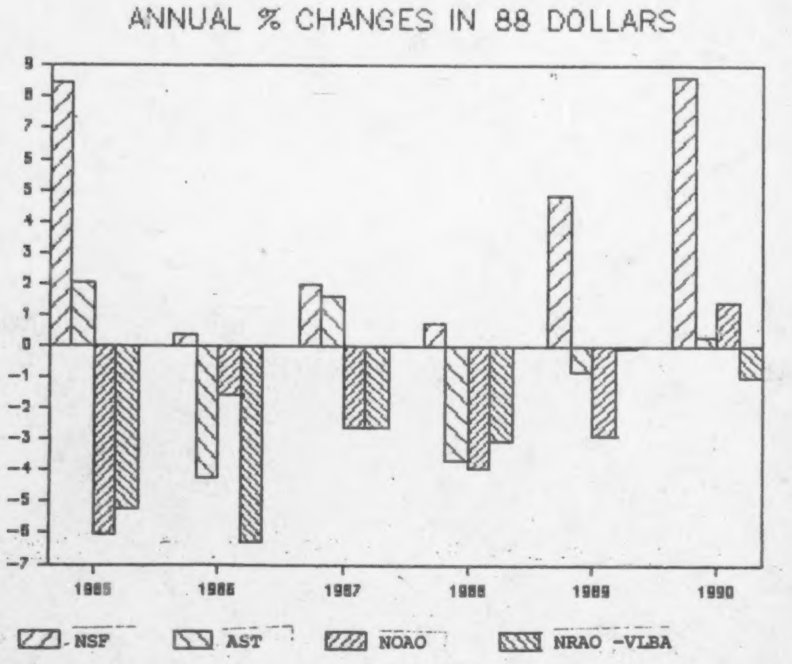
jr

Enclosures:
1. NSF Budget--Astronomy Funding for 1984-89
2. Science Magazine Article
3. Summary Outline of the Plan for the Future of the National Optical Astronomy Observatories
4a. Report of NSF's Committee on Optical Astronomy (Tape Committee)
4b. Letter from Mr. Harry Albers to Dr. Warren Baker of the National Science Board
5. Value of Astronomy for Science and Technology
6. Wide Recognition of Merits of Astronomy
7. Relationship between Groundbased and Space Astronomy
8. Comments on European and US Programs in Groundbased Astronomy

Enclosure 1

NSF BUDGET
Astronomy Funding 1984-89





FEBRUARY 14, 1989

NSF Budget

Year	1984	1985	1986	1987	1988	1989	1990
NAIC	6.1	6.1	5.7	5.9	5.9	6.3	6.4
Optical	23.2	22.8	22.7	23.1	23.3	23.7	25.2
VLBA	2.5	9.0	8.6	11.4	11.6	12.0	12.4
Rad-VLBA	17.8	17.7	16.7	17.0	17.3	18.1	18.8
Tot.Radio	20.3	26.7	25.3	28.4	28.9	30.1	31.2
Tot. Ctr.	49.5	55.5	53.7	57.4	58.1	60.1	62.8
Grants:	27.8	27.2	26.5	27.7	27.9	29.2	31.2
Other:	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Astronomy:	77.3	82.8	80.2	85.0	86.0	89.3	94.0
NSF:	1320.3	1501.8	1523.9	1623.0	1717.0	1885.0	2149.0

In 1988 $s

Year	1984	1985	1986	1987	1988	1989	1990
NAIC	7.1	6.7	6.3	6.2	5.9	6.0	5.8
Optical	26.9	25.3	24.9	24.3	23.3	22.6	23.0
VLBA	2.9	10.0	9.4	12.0	11.6	11.5	11.3
Rad-VLBA	20.6	19.6	18.3	17.8	17.3	17.3	17.1
Tot.Radio	23.5	29.5	27.7	29.8	28.9	28.7	28.4
Tot. Ctr.	57.6	61.5	58.9	60.2	58.1	57.4	57.1
Grants:	32.3	30.2	29.0	29.0	27.9	27.9	28.4
Other:							
Astronomy:	89.9	91.7	87.9	89.3	86.0	85.3	85.6
NSF:	1534.5	1664.3	1670.6	1704.0	1717.0	1800.2	1955.6
De/inflator: (Percent)	16.2	10.8	9.6	5.0	0.0	-4.5[1]	-9.0[1]

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[1] Assumed

[1] Assumed

FEBRUARY 14, 1989

Percent share in NSF budget

Year	1984	1985	1986	1987	1988	1989	1990
NAIC	0.5	0.4	0.4	0.4	0.3	0.3	0.3
Optical	1.8	1.5	1.5	1.4	1.4	1.3	1.2
VLBA	0.2	0.6	0.6	0.7	0.7	0.6	0.6
Rad-VLBA	1.3	1.2	1.1	1.0	1.0	1.0	0.9
Tot.Radio	1.5	1.8	1.7	1.7	1.7	1.6	1.5
Tot. Ctr.	3.8	3.7	3.5	3.5	3.4	3.2	2.9
Grants:	2.1	1.8	1.7	1.7	1.6	1.5	1.5
Other:							
Astronomy:	5.9	5.5	5.3	5.2	5.0	4.7	4.4
NSF:	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Percent change versus prior year in 1988 $s

Year	1984	1985	1986	1987	1988	1989	1990
NAIC	NA	-5.6	-6.5	-1.6	-3.9	1.9	-4.4
Optical	10.9	-6.0	-1.6	-2.6	-3.9	-2.9	1.4
VLBA	NA	243.3	-6.0	27.7	-3.1	-1.2	-1.5
Rad-VLBA	-17.8	-5.2	-6.3	-2.6	-3.1	-0.1	-1.0
Tot.Radio	-6.3	25.4	-6.2	7.6	-3.1	-0.5	-1.2
Tot. Ctr.	16.5	6.9	-4.3	2.3	-3.5	-1.2	-0.5
Grants:	26.2	-6.6	-3.9	0.2	-4.0	0.0	1.9
Other:							
Astronomy:	19.8	2.0	-4.2	1.6	-3.7	-0.8	0.3
NSF:	16.9	8.5	0.4	2.0	0.8	4.8	8.6

FEBRUARY 14, 1989

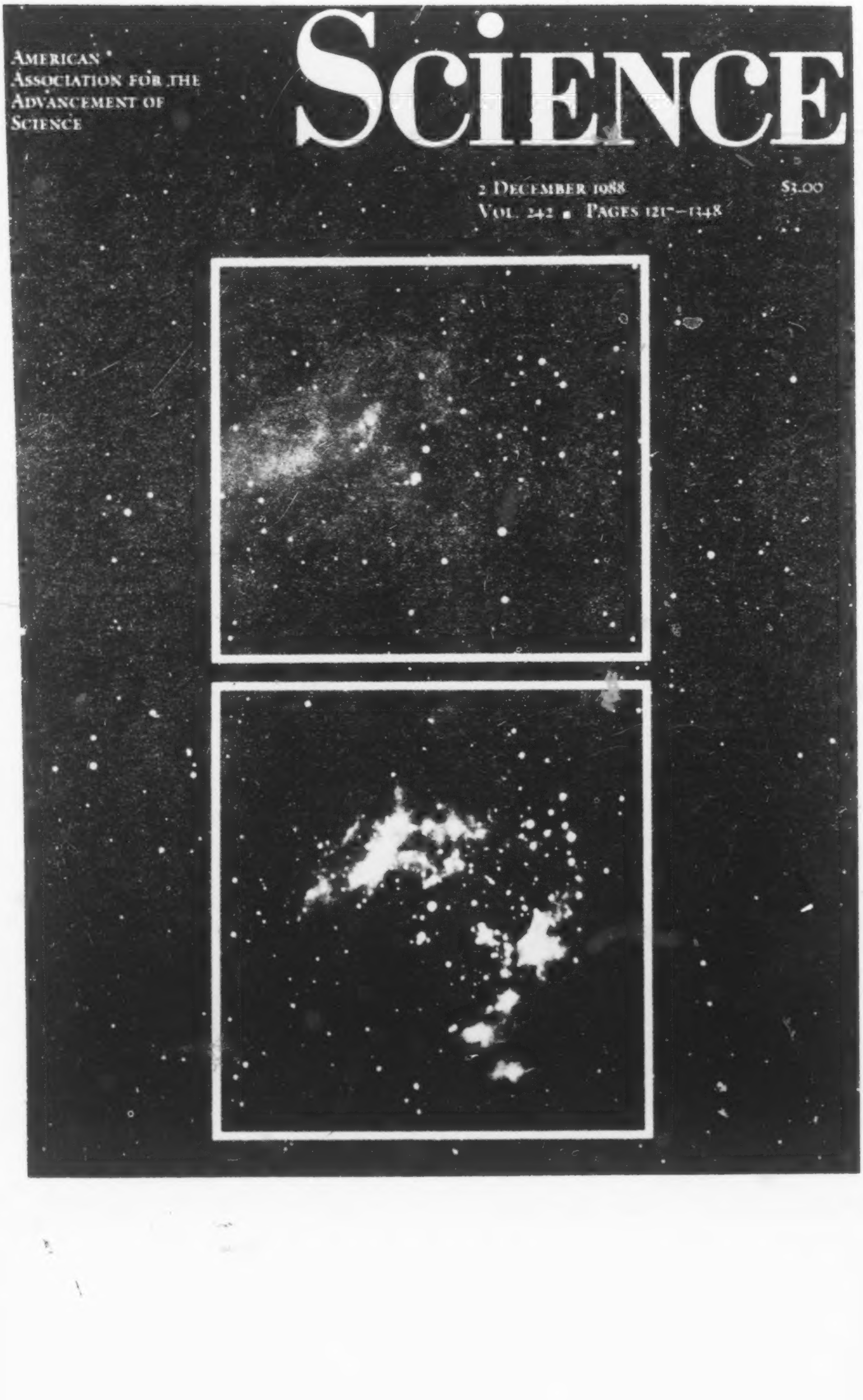
Percent change vs. 1984 in 1988 $s

Year	1984	1985	1986	1987	1988	1989	1990
NAIC	0.0	-5.6	-11.7	-13.1	-16.5	-14.9	-18.6
Optical	0.0	-6.0	-7.5	-9.9	-13.4	-15.9	-14.7
VLBA	0.0	243.3	222.6	311.9	299.2	294.4	288.4
Rad-VLBA	0.0	-5.2	-11.2	-13.5	-16.2	-16.3	-17.1
Tot.Radio	0.0	25.4	17.7	26.6	22.7	22.1	20.6
Tot. Ctr.	0.0	6.9	2.3	4.7	1.0	-0.2	-0.7
Grants:	0.0	-6.6	-10.3	-10.1	-13.7	-13.7	-12.0
Other:							
Astronomy:	0.0	2.0	-2.2	-0.7	-4.3	-5.1	-4.8
NSF:	0.0	8.5	8.9	11.0	11.9	17.3	27.4

Enclosure 2

The lead article in Science Magazine (December 2, 1988) features NOAO research. The article shows how new detector technology led to a 10,000 to 100,000-fold increase in telescope efficiency for infrared light which can penetrate the dust clouds in space which obscure many parts of our universe. This opened up new vistas such as unique views of "star nurseries" within dust clouds and of the center of our own milky way galaxy.

Copy of article follows.



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ASSOCIATION FOR THE
ADVANCEMENT OF
SCIENCE

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Astronomical Imaging with Infrared Array Detectors

IAN GATLEY, D. L. DEPOY, A. M. FOWLER

History shows that progress in astronomy often stems directly from technological innovation and that each portion of the electromagnetic spectrum offers unique insights into the nature of the universe. Most recently, the widespread availability of infrared-sensitive two-dimensional array detectors has led to dramatic improvements in the capabilities of conventional ground-based observatories. The impact of this new technology on our understanding of a wide variety of phenomena is illustrated here by infrared pictures of star-forming regions, of nebulae produced by the late stages of stellar evolution, of the nucleus of our own galaxy (the Milky Way), and of activity in other galaxies.

IN THIS CENTURY WE HAVE LEARNED BY EXPERIENCE THAT novel types of astronomical observation often lead to the discovery of new phenomena. We have, for example, witnessed the excitement that followed the inception of radio and x-ray astronomy and are no longer astonished by such concepts as that of neutrino astronomy. The fundamental importance of opening every conceivable observational window on our universe is widely appreciated.

One of the earliest demonstrations of this perspective was Sir William Herschel's well-known measurement of infrared radiation from the sun, made in 1800. Perhaps, then, it is surprising that infrared astronomy has not yet been fully exploited. This is especially true for those infrared wavelengths that penetrate through the earth's atmosphere, because they can be focused with existing "optical" telescopes. Yet no efficient way of imaging this infrared radiation existed until recently. Rather, because of the limitations on the existing technology and instrumentation, crude pictures were built up slowly and painfully using single detectors, by moving the telescope in a raster pattern.

To make images with single detectors is inefficient in obvious ways. Because the telescope must be pointed separately at each individual picture element, the procedure is inordinately time-consuming. Further, it limits the spatial accuracy of the image, discouraging work at high magnification and, since the data are taken serially, it maximizes susceptibility to variations in atmospheric conditions and instrumental performance.

Despite these difficulties, observations at infrared wavelengths are important because of several unique advantages. First, many cool objects (with temperatures less than about 1000 K) radiate predominantly in the infrared—these include, for example, low mass stars, planets, and clouds of circumstellar or interstellar dust. Second, infrared radiation penetrates through obscuring dust very much more easily than optical light; as we will see later, the center of our galaxy—the Milky Way—is undetectable in visible light, but is extremely bright in the infrared. Third, because of the cosmological redshift, the optical features of distant objects move to longer wavelengths. To compare the optical characteristics of very distant quasars and galaxies with their nearby counterparts, infrared measurements are required. (Although the term "infrared" is widely used to describe any wavelengths between 1 and 1000 μm, we will confine our attention here to results obtained in the wavelengths interval between 1 and 2.5 μm.)

Over the last two decades a community of dedicated astronomers has succeeded in demonstrating some of the virtues of infrared astronomy with primitive instruments, and, ever conscious of the potential advantages of even a modest camera, they have also vigorously pursued the possibility of technological innovations.

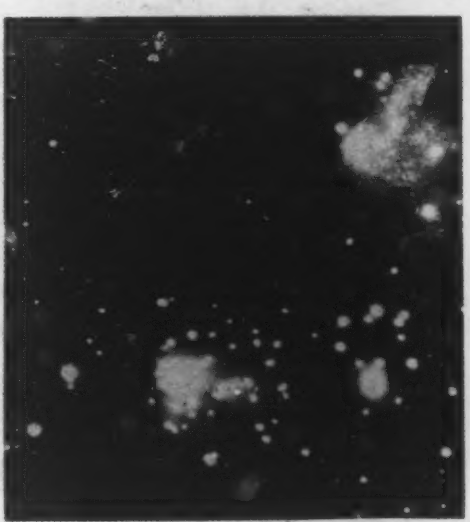

Fig. 1. Comparison of optical and infrared images of the star formation region NGC 2024 taken at (**top**) 0.7 μm, close to the red end of the visible range, and (**bottom**) 2.2 μm. The pictures were taken at the Kitt Peak National Observatory and are printed courtesy of R. Probst.

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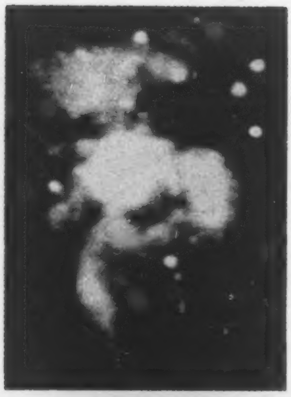


Fig. 2. An infrared image of Sharpless 106. The colors in the picture were produced similarly to the colors in the M17 picture on the cover. The picture was made with the University of Hawaii 2.24-m telescope at the Mauna Kea Observatory and is printed courtesy of K. Hodapp and E. Becklin.

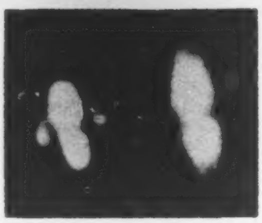


Fig. 3. Infrared pictures of CRL 2688 taken through (**right**) a wide bandpass filter centered on 1.25 μm and (**left**) a narrow bandpass filter centered on 2.122 μm, the wavelength of a strong molecular hydrogen emission line. No correction has been made for the continuum emission also present at this wavelength. As described in the text, a ring of emission appears at the "waistline." The images were made with the Kitt Peak National Observatory 1.3-m telescope in collaboration with B. Balick and B. Zuckerman.

Earlier this decade, encouragement came from the results of two camera projects, one at the NASA/Goddard Space Flight Center (*1*), the other at the University of Rochester (*2*), the former operating at wavelengths around 10 μm, and the latter from 1 to 5 μm. In both cases, despite the modest detector sensitivity, useful astronomical images were obtained.

Over the last few years major development efforts based on several different technologies, and often involving close collaboration between universities, industry, and government agencies, have gone ahead. By chance, many of these programs have achieved success simultaneously; in March 1987, at a remarkable meeting in Hawaii, a large number of exciting astronomical results obtained with two-dimensional infrared arrays were presented (*3*). Most of the detectors had been so recently commissioned that a telling bias emerged in the conference—the majority of the targets were in the wintertime sky!

The sudden impact on astronomy of sensitive two-dimensional arrays of infrared detectors—containing thousands of detectors, each more sensitive than the single detectors of earlier experiments—is the subject of this review. The changes in capability and perspective induced by this technological revolution are necessarily both profound and cumulative. We therefore feel the need to stress several points. First, the capability to make infrared images is suddenly rather widely available, and several viable technologies exist. Second, the pictures used to illustrate infrared imaging in the remainder of this review were obtained at a variety of observatories with these different technologies and many of the pictures have been kindly and enthusiastically provided by our colleagues. Third, it was difficult to decide which examples to choose and our choices were fairly arbitrary. Finally, it is our expectation and hope that these examples (and our descriptions of their astrophysical significance) will seem primitive when compared with the pictures that will be produced next year.

Star Formation Regions

How stars form is obviously of fundamental importance to astronomy. We know that massive stars form in clusters inside giant molecular clouds, but these clouds are dusty, and star formation is inefficient. Inevitably, then, the remnant cloud material obscures our view of star formation. Eventually the interactions between the massive young stars and the molecular cloud (such as stellar winds, whose effects are illustrated in the next section, and ionization of the gas by ultraviolet radiation) may disrupt the cloud sufficiently to render the stars detectable in optical light—the Orion Nebula is a familiar example.

To study the earliest phases of star formation, however, we must overcome the effects of obscuration. Infrared radiation penetrates through the dust; for example, if the dust attenuates the optical radiation by a factor of 1 million, then the infrared emission at 2 μm is attenuated only by a factor of 4.

Near the famous Horsehead Nebula in the obscured star-forming region NGC 2024 is the radio source Orion B. The radio emission in Orion B originates from a hydrogen plasma ionized by the ultraviolet radiation from the young stars. Fifteen years ago, infrared observations found a bright embedded star (*4*), but theory showed that this object was not sufficiently luminous to power the radio source alone (*5*). The generic problem of locating the members of young clusters embedded in their parent molecular cloud recurred in the study of star formation, simply because it was difficult to pursue such observational problems until infrared array detectors became available. Then, suddenly, it became trivial. We may compare images of the NGC 2024 region at wavelengths of 0.7 and 2.2 μm (Fig. 1). The dense dust lane that prevents us from detecting optical light from the young stellar cluster is penetrated in the 2.2-μm image. The nebulosity in the infrared image, like the radio emission, comes from the Orion B plasma.

On the cover of this issue is another example of star formation, the Omega Nebula (Messier 17). This spectacular nebula was discovered long ago by optical methods, but comparison of the optical and infrared images reveals that much of the source is heavily obscured by the dust in the molecular cloud. To illustrate the variations in the infrared colors throughout M17, three images were taken through infrared filters at wavelengths of 1.2, 1.65, and 2.2 μm; these three images have been displayed simultaneously in blue, green, and red, respectively. In other words, this is how M17 would look if the human eye responded to infrared rather than optical radiation, detecting wavelengths about three times longer than those of visible light. Some 80% of the hundreds of stars in this image were not detected before the advent of infrared imagers.

As in the case of Orion B, the nebulosity in M17 is plasma emission from hydrogen ionized by the radiation from the young stars. The variations in the apparent color of the nebula are caused by variations in the amount of foreground dust, as follows. We have already seen that longer wavelength radiation penetrates through the dust more readily; a corollary to this fact is that, as the amount of extinction by dust increases, the emergent radiation appears "redder." The optical picture of M17 is abruptly truncated at the right edge of the nebula, as the dust gets thicker; correspondingly, the infrared nebula appears systematically redder towards the right of

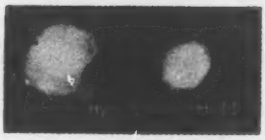


Fig. 4. A pair of infrared pictures of the planetary nebula NGC 7027 taken through filters which isolate radiation from molecular (**left**) and ionized atomic (**right**) hydrogen gas. The pictures were taken with the IRCAM instrument at the United Kingdom Infrared Telescope, Mauna Kea, Hawaii, courtesy of I. McLean.

the picture. It turns out that the most luminous part of M17 is totally invisible in optical photographs. The core of the M17 molecular cloud, one of the most massive in the galaxy, lies at the lower right of the region illustrated here (*6*); the total luminosity of the young stellar cluster is approximately 6 million times that of the sun (*7*).

A young star emerges from its parent cloud. Observations of radio molecular emission lines at millimeter wavelengths have shown that stellar winds from young massive stars are important in breaking up the "cocoon" of material left over from the collapse process that formed the star (*8*). The outflow of molecular material is often "bipolar," that is, it streams in two opposing directions. This bipolarity is probably related to the density structure in the "cocoon." In particular, any slight initial rotation of the parent molecular cloud prior to the cloud collapse will (after the huge scale change involved in the process, and because of conservation of angular momentum) cause the formation of a disk. The disk will collimate the stellar wind (in the direction perpendicular to the plane of the disk) and cause the bipolar flow.

An infrared image of Sharpless 106 (color-coded similarly to the earlier picture of M17), provides an example of a bipolar nebula viewed from a particularly favorable orientation, edge-on to the disk (Fig. 2). The young star is located in the disk, which separates the two lobes. The dust in the disk is responsible for the red color of the nebula at the edges of the disk and the red or orange color of background stars shining through the disk, which plainly suffer substantial amounts of extinction and reddening.

Planetary Nebulae: Late Stages of Stellar Evolution

The final stages of stellar evolution often involve the loss of material from the star, and the formation of circumstellar nebulae. When the mass loss is extreme, there is enough material in these nebulae to extinguish the optical light from the star. It is straightforward to see the importance of infrared observations in such cases. Less highly obscured mass-loss nebulae, including the famous and often photographed "planetary nebulae" (of which the Ring and the Dumbbell nebulae are well-known examples) are also good targets for infrared cameras. The reason is that a critical observational strategy is uniquely available in the infrared, namely, to observe emission lines from the hydrogen molecules. [Although we will illustrate molecular hydrogen imaging only for the case of planetary nebulae, the technique can be applied in many circumstances. One may confidently predict that it will be widely used, and with important consequences (*9*). Indeed one might have expected that observations of molecular hydrogen, which is astrophysically the most abundant molecule by an overwhelming factor, would dominate the field of molecular line astronomy. The hydrogen molecule, however, is homonuclear—and so lacks a dipole moment—which implies immediately that its emission lines will be weak compared to those of many other (less abundant) molecules; furthermore it is difficult to excite. Suffering neither disadvantage, the CO molecule has been widely observed in astronomy. The hydrogen molecule is excited in astrophysical shocks with velocities in the approximate range 10 to 50 km/s, and by ultraviolet light in the wavelength interval 912 to 1108 Å (*10*); the electric quadrupole transitions of its vibration-rotation spectrum can be observed in the infrared.]

As it happens, both molecular hydrogen excitation mechanisms may plausibly operate in planetary nebulae, because the mass loss wind from the central star can shock the envelope, and ultraviolet radiation sufficient even to ionize portions of the envelope is emitted from the stellar remnant. Fortunately the relative strengths of the emission lines resulting from the two excitation mechanisms are very different, and so we can distinguish between them.

The ionized gas in planetary nebulae is easy to detect, and has been studied in detail, but detection of the neutral component presents more of a technical challenge. We need to know the distribution of the neutral gas in order to attack a fundamental unsolved question, namely, that of the physical mechanism that ejects and shapes the outflowing envelope. An interesting form of planetary nebulae, the "bowtie" or "butterfly"—typified by the Dumbbell nebula (Messier 27)—commonly shows molecular hydrogen emission (*11*). We have observed a dense molecular toroid around the "waistline" of several of these objects; Fig. 3 is an image of a nebula known as CRL2688 (the toroid appears in projection as two circular patches at the waistline). The morphological similarity between this bipolar nebula and the young object Sharpless 106 is striking; the appearance of each is dictated by the presence of a dense disk that collimates an outflow.

CRL2688 was easily identified as a bipolar nebula from optical observations. Another planetary nebula, NGC 7027, exhibits no hint of bipolarity in optical or radio data (Fig. 4). The ionized gas distribution, labeled H II (imaged here in the $n = 7 \rightarrow 4$ recombination line of atomic hydrogen at 2.17 μm), forms a bright oval shell. In sharp contrast, the molecular hydrogen image exhibits a bipolar structure and a dense toroid.

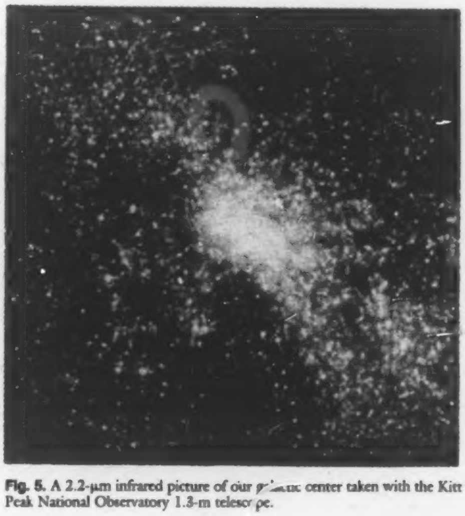


Fig. 5. A 2.2-μm infrared picture of our galactic center taken with the Kitt Peak National Observatory 1.3-m telescope.

The Center of Our Galaxy

The nuclei of galaxies are regions of high stellar density that often exhibit remarkably energetic activity. The energy density is sometimes so high that the only "conventional" physical explanation available is that of emission from the accretion disk of a black hole. The nucleus of our own galaxy—the Milky Way—is some 100 times closer than even the nearest neighboring spiral galaxy, Andromeda. This simple fact provides us with a compelling motivation to study the galactic center, for we are guaranteed to obtain detailed information unavailable to us elsewhere; but, there is a problem. The outer part of our galaxy is an enormous, flattened, very dusty disk (exactly like that seen in many familiar pictures of distant galaxies). We live out in the disk. Optical astronomers cannot, therefore, exploit our proximity to the nucleus, because the intervening dust obscures optical radiation.

The position of the nucleus was determined by infrared observations in 1968 (*12*), and a large body of information has been painstakingly accumulated since then by infrared and radio observers, as described, for example, in the recent symposium to honor Charles Townes (*13*). Considerable effort and ingenuity have been expended in the pursuit of observational data and in their interpretation. There is evidence for significant nuclear activity, corresponding to an energy output some 10 million times that of the sun. There has been lively discussion of the implications of this result, which may be attributable to star formation, or may perhaps be emission from the accretion disk of a black hole. Useful tests of the various hypotheses are provided, for example, by the study of the stellar population, by measurements of the radial distribution of starlight, and by determination of the kinematics of the stars and the gas.

The impact of infrared cameras on this field is enormous. A striking instance is Fig. 5, which was obtained in less than 1 hour on a 50-inch (1.3-m) telescope, and which shows a 2.2-μm image of the central 100 light-years of our galaxy. The nucleus is prominent at the center. Thousands of stars are detected, and the direction of the plane of the galaxy, which runs from upper left to lower right, is evident. A large patch of extinction runs parallel to the plane, displaced down to the left; this is caused by dust in the galactic plane. One may immediately deduce that our vantage point (that is, the solar system) is actually slightly displaced above the plane of the galaxy.

More importantly, this image provides some perspective on the practical issues involved in the studies of the galactic center, and vividly demonstrates how vast a strategic problem confronted the observer using a single detector. It would have been necessary to point the telescope at half a million positions on the sky in order to build up a picture like Fig. 5. The reward for such a heroic effort would have been to confront head-on the question of which of these thousands of stars needed to be studied in more detail; and, remember, they would need to be studied one at a time!

Virtually every experiment performed before arrays, then, was necessarily based on preconceived ideas about the problem. The new detectors remove this bias. Discoveries generally follow swiftly in such circumstances. The first round of activity will naturally be to improve our determination of those physical quantities relied upon most heavily in current analyses: the types of stars present, the extinction they suffer from intervening dust, and their distribution in space; the excitation of the ionized and molecular gas; the dynamics of the gas and stars. All this, and more, while diligently searching for anomalies suggestive of a black hole.

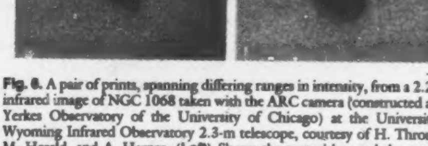


Fig. 6. A pair of prints, spanning differing ranges in intensity, from a 2.2-μm infrared image of NGC 1068 taken with the ARC camera (constructed at the Yerkes Observatory of the University of Chicago) at the University of Wyoming Infrared Observatory 2.3-m telescope, courtesy of H. Thronson, M. Hereld, and A. Harper. (**Left**) Shows the central bar and the compact bright nucleus. (**Right**) Including a wider range in intensities, shows the spiral structure of the galaxy.

Activity in Other Galaxies

In other galaxies both the amount of star formation activity and the luminosity of the nucleus is sometimes far in excess of that in our galaxy. This is demonstrable from optical observations alone, but we can confidently anticipate (from consideration of the infrared pictures of our own galaxy) that infrared pictures of other galaxies will provide new insights.

For example, the galaxy NGC 1068 has a bright nucleus surrounded by a very luminous star-forming region some 10,000 light-years in diameter (*14*). Speculation about the relationship, if any, between the compact nuclear source and the extended star-forming region has abounded. Accretion of material onto the nucleus, or the triggering of star formation by an explosion in the nucleus, are popular scenarios. The discovery, made by the Infrared Astronomy Satellite (IRAS) satellite (*15*), of a possible correlation between nuclear luminosity and the presence of stellar bars (*16*) led to suggestions that barlike structures are important in radial transport of material, but optical observations failed to reveal a bar in NGC 1068. The optical observations may, of course, have been hampered by dust, and are also strongly biased by the bright emission from the recently formed stars. Infrared observations, besides penetrating the dust, are excellent tracers of the underlying stellar mass distribution, because both relatively cool, long-lived, low mass stars—which comprise the bulk of the stellar mass—and old, highly evolved giant stars—whose current distribution has been determined by the gravitational potential of the galaxy—radiate predominantly in the infrared.

Figure 6 is composed of a pair of prints, spanning differing ranges of intensity, produced from a 2.2-μm infrared image of NGC 1068 (*17*). The print on the right exhibits spiral structure in the galaxy similar to that seen in optical photographs. The print on the left reveals a clear stellar bar, with stubby spiral arms emanating from either end. These arms join perfectly onto molecular arm features discovered in radio interferometric observations (*18*), providing stimulating support for the notion of stellar bars as triggers for circumnuclear mass transport and star formation.

On the other hand, NGC 253, a nearby starburst galaxy which seemed from optical and earlier infrared scanning measurements (*19*) to lend additional support to this theory of stellar bars, gives a different impression when imaged in the infrared. Figure 7 is made from optical and infrared pictures of NGC 253. The optical picture is obviously heavily affected by dust. The infrared picture, although confirming the existence of the elongated structure found in the earlier work, shows that the "bar" bends, and must be at least in part a spiral arm. Furthermore, there is no barlike distortion of the brightness distribution approaching the starburst nucleus. An infrared survey of barred spiral galaxies will surely help clarify the role of stellar bars, if any, in transporting "fuel" inward toward the nuclei of galaxies. The color infrared picture here is displayed in "false color": the different colors correspond to differing levels of intensity

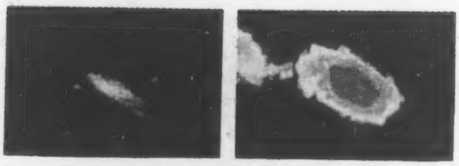
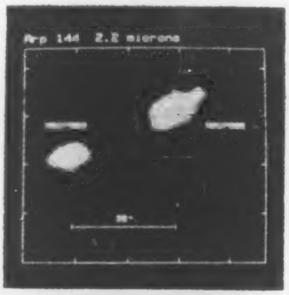


Fig. 7. Comparison of optical and infrared images of NGC 253. (**Left**) A color optical picture, reprinted with permission of the Anglo-Australian Telescope Board. (**Right**) A false color 2.2-μm infrared picture of NGC 253 taken at the Steward Observatory of the University of Arizona with the 61" telescope, courtesy of G. Rieke and M. Rieke. The scales are not the same.

Fig. 8. A false color 2.2-μm infrared image of Arp 144 taken with the University of Texas McDonald Observatory 2.7-m telescope, courtesy of M. Joy and P. Harvey.



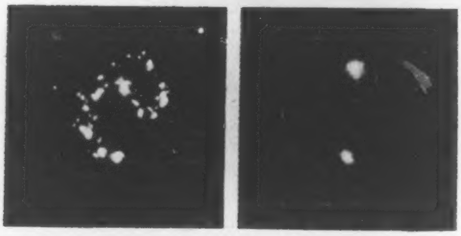


Fig. 9. Comparison of an archival KPNO optical picture (**left**) and a 1.65-μm infrared image (**right**), both in false color, of NGC 4038 and NGC 4039 taken with the Kitt Peak National Observatory 2.1-m telescope. The scales are not the same.

(brightness) for radiation at a single wavelength, rather than radiation at different wavelengths.

Galaxies in Collision

Stars form in molecular clouds, and external triggers (such as the action of the stellar bar in NGC 1068) may stimulate and enhance the process. Perhaps the ultimate example of a trigger is the collision of two galaxies. As well as causing star formation, such a collision would very probably deposit material onto the galactic nuclei, "force-feeding" the accretion disk of a black hole, if one were present. These are plausibly the reasons why the IRAS satellite found interacting galaxies as a class to be the most luminous systems in the universe. The interaction stirs up the interstellar material in the galaxies, causing severe, clumpy extinction. This extinction and the bright emission from regions of induced star formation conspire to produce a chaotic appearance in optical photographs. The large variety of possible outcomes from galaxy/galaxy interactions is briefly illustrated by three examples.

Optical studies of the galaxy Arp 144 (NGC 7828/29) revealed a seemingly empty "folded ring" (NGC 7828) with a spheroidal companion (NGC 7829); this unusual structure was believed to be a spiral galaxy whose disk had been stripped away in a collision with an (invisible) intergalactic cloud of atomic hydrogen (*20*). The infrared image in Fig. 8 shows that Arp 144 was actually formed by an encounter between two similarly massive galaxies (*21*). The extinction within the ring of NGC 7828 is very high, and hides the nucleus at optical wavelengths.

A second interaction is illustrated in Fig. 9, which is composed of the optical and infrared images of the NGC 4038/4039 system. The optical image is dramatically disturbed, speckled with bright centers of star formation, and mottled with dark patches of dust. It is difficult to distinguish the nuclei of the two colliding galaxies. The infrared image is much less chaotic, penetrates through the dust, and shows the distribution of stellar mass in the galaxies rather well.

It has proved difficult to classify interacting galaxies from optical photographs because of the wide variety in their appearance, which has been illustrated, for example, in Arp's *Atlas of Peculiar Galaxies* (*22*). Interacting galaxies are valuable "test particles" for various theoretical formalisms, and infrared images can provide a clear picture of the underlying stellar mass distributions. The possibility exists that classification may be more tractable from infrared images; an infrared survey of interacting galaxies is now feasible. Possibly the components will prove recognizable within the classification scheme used for undisturbed galaxies, in which case we can make a major step, and identify the types of galaxies that collided.

The impact of the technological revolution reported here may be seen in images of even very familiar systems; Fig. 10, for example, is composed of optical and infrared images of the famous "Whirlpool" galaxy (Messier 51). This galaxy was the first in which spiral structure was recognized, in 1845.

The arms of the large spiral appear much more regular in the infrared picture than in the optical. The outlying arm, which joins to the companion, is strikingly faint in the infrared, suggesting that much of its optical luminosity is from young stars formed in the galaxy/galaxy interaction. The companion galaxy is clearly shown by the infrared image to be a barred spiral.

The Detectors

The majority of infrared arrays available today are hybrid devices, resulting from a process in which the detectors and readouts are manufactured separately. The readout circuit is fabricated on silicon in the same way as integrated circuits, whereas the detectors are made, for example, from mercury cadmium telluride (HgCdTe), indium antimonide (InSb), platinum silicide (PtSi), or extrinsic doped silicon (Si:X). Then the two chips are sandwiched together, with the electrical interconnections being made by indium bumps on each of the chips [see (*3*) for details of the construction]. Most of the arrays in use at telescopes today were obtained through collaborations with industry, NASA, or the Department of Defense.

The images included in this article were made with four different types of detector arrays, by observers at a number of institutions, as described in the next paragraph. These arrays share the property that each consists of thousands of detector elements, and that each element of the array outperforms the single detectors of earlier experiments. Briefly, these devices are:

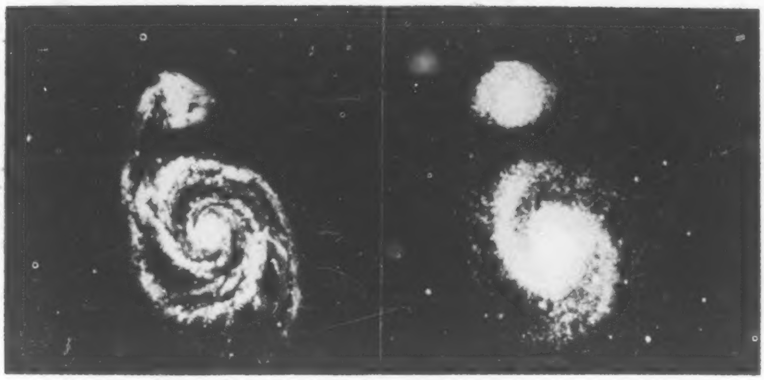


Fig. 10. Comparison of an archival KPNO optical picture (**left**) and a 1.65-μm infrared picture (**right**) of M 51. The infrared picture was taken with the Kitt Peak National Observatory 1.3-m telescope. The scales are not the same.

1) A 128 by 128 HgCdTe array with a Reticon metal-oxide semiconductor field effect transistor (MOSFET) multiplexer readout, manufactured by Rockwell Science Center for the Jet Propulsion Laboratory (JPL/HIRIS) and operated by the University of Hawaii (see Fig. 2).

2) A 64 by 64 HgCdTe array with a direct-injection input surface-channel charge-coupled device (CCD) readout manufactured by Rockwell Science Center, and operated both by the University of Arizona and the Astrophysics Research Consortium (ARC) (see Figs. 6 and 7).

3) A 58 by 62 InSb array with a source follower input MOSFET multiplexer readout manufactured by Santa Barbara Research Center, and operated by the University of Texas at Austin, the United Kingdom Infrared Telescope (UKIRT), and the National Optical Astronomy Observatories (NOAO) (see Figs. 1, 3, 4, and 8).

4) A 256 by 256 platinum silicide Schottky barrier diode array with a source follower input MOSFET multiplexer readout, manufactured by Hughes Aircraft Co., and operated by the Infrared Research and Development Group of the National Optical Astronomy Observatory (NOAO/IR&D) (see Figs. 5, 9, and 10 and the cover of this issue).

The HgCdTe array from Rockwell Science Center and the InSb array from Santa Barbara Research Center are available commercially.

Future Prospects

The examples presented here demonstrate the utility and viability of infrared imaging as a tool in astronomy, but rapid improvements in the technology will continue for some time yet. The detector arrays we have described here were an outgrowth of the technology developed by the defense industry for military applications. Feedback to the manufacturers following their first use for astronomy has meant that more recent arrays are being optimized for use in astronomy by improvement in noise and dark-current performance, by modification of the wavelength response, and by changes in readout designs. The number of detector elements in the arrays will continue to be increased, and formats as large as 256 by 256 will be in widespread use within 2 or 3 years.

Although we have concentrated here on the wavelength interval 1 to 2.5 μm, the same principles of array construction are applicable out to wavelengths at least as long as 30 μm, and the same intrinsically high detector sensitivities can be achieved. The realization of the full potential of the arrays at these longer wavelengths is more difficult however, because of the large thermal backgrounds emitted by the atmosphere and the telescopes themselves; a number of groups are already using arrays at longer wavelengths, and there is rapid progress in learning how to cope with the thermal background.

Further strides can be made with array detectors in space, where the thermal background can be eliminated by cooling the telescope; the gains achieved by IRAS were possible because of its cooled telescope (*23*), but this telescope did not have the benefit of arrays. The European Space Agency's Infrared Space Observatory (ISO) will combine a cold telescope with some use of arrays, and both features will be fully exploited by NASA's Space Infrared Telescope Facility (SIRTF) (*24*). NASA is also planning to reach the full resolution available with the Hubble Space Telescope (HST) by outfitting it with a second generation instrument equipped with infrared arrays.

REFERENCES AND NOTES

1. J. F. Arens *et al.*, *Proc. Soc. Photo Opt. Instrum. Engin.* **280**, 61 (1981).
2. W. J. Forrest and J. L. Pipher, in *Proceedings of the Infrared Detector Technology Workshop*, C. R. McCreight, Ed. (U.S. Government Printing Office, Washington, DC, 1983), pp. 161–169.
3. C. G. Wynn-Williams and E. E. Becklin, Eds., *Infrared Astronomy with Arrays* (University of Hawaii, Institute for Astronomy, Honolulu, 1987).
4. G. L. Grasdalen, *Astrophys. J.* **193**, 373 (1974).
5. E. Krugel, C. Thum, J. Martin-Pintado, H. Pankonin, *Astron. Astrophys. Suppl. Ser.* **48**, 345 (1982).
6. B. G. Elmegreen, C. J. Lada, D. F. Dickinson, *Astrophys. J.* **230**, 425 (1979).
7. D. A. Harper, F. J. Low, G. H. Rieke, H. A. Thronson, *ibid.* **205**, 136 (1976).
8. R. L. Snell, in *Star Forming Regions, Proceedings of the 115th IAU*, M. Peimbert and J. Jugaku, Eds. (Reidel, Dordrecht, 1985), pp. 213–237.
9. I. Gatley, in *Galactic and Extragalactic Star Formation, NATO Advanced Study Institute*, G. Fick and R. Pudritz, Eds. (Reidel, Dordrecht, 1988), pp. 159–179.
10. J. H. Black and E. F. van Dishoeck, *Astrophys. J.* **322**, 412 (1987).
11. B. Zuckerman and I. Gatley, *ibid.* **324**, 1222 (1988).
12. E. E. Becklin and G. Neugebauer, *ibid.* **151**, 145 (1968).
13. D. C. Backer, Ed. *The Galactic Center. Proceedings of the Symposium Honoring C. H. Townes* (American Institute of Physics, New York, 1987).
14. C. M. Telesco, E. E. Becklin, C. G. Wynn-Williams, D. A. Harper, *Astrophys. J.* **282**, 427 (1984).
15. H. J. Habing and G. Neugebauer, *Sci. Am.* **251**, 49 (November 1984).
16. T. G. Hawarden, J. H. Fairclough, R. D. Joseph, S. K. Leggett, in *Light on Dark Matter*, F. P. Israel, Ed. (Reidel, Dordrecht, 1985), pp. 455–466.
17. H. A. Thronson *et al.*, *Astrophys. J.*, in press.
18. S. T. Meyers and N. Z. Scoville, *ibid.* **312**, L39 (1987).

19. N. Z. Scoville *et al.*, *ibid.* 289, 129 (1985).
20. K. C. Freeman and G. de Vaucouleurs, *ibid.* 194, 569 (1974).
21. M. Joy *et al.*, *ibid.* 330, L29 (1988).
22. H. Arp, *Atlas of Peculiar Galaxies* (California Institute of Technology, Pasadena, 1966).
23. G. Neugebauer *et al.*, *Science* 224, 14 (1984).
24. G. H. Rieke *et al.*, *ibid.* 231, 807 (1986).
25. This article reports the success of the community of people who do infrared astronomy: we are especially grateful to J. Arens, E. Anderson, B. Balick, J. Barnes, P. Britt, N. Buchholz, G. Burbidge, E. Becklin, L. Davis, W. Forrest, M. Fowler, S. Gaalema, J. Gates, Cathy and Sam Gatley, F. Gillett, K. Gillies, M. Hanna, A. Harper, P. Harvey, M. Hereld, K. Hodapp, M. Joy, R. Joyce, C. Lada, J. Little, I. McLean, M. Merrill, J. Pipher, R. Probst, G. Rieke, M. Rieke, F. Stuart, H. Thronson, S. Wolff, and B. Zuckerman. The National Optical Astronomy Observatories are operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.

COVER A archival Kitt Peak National Observatory 4-meter telescope color optical picture (top) and a color infrared picture (bottom) of Messier 17, a region of vigorous star formation. The infrared picture is a composite of images made through 1.2-mircrometer, 1.65-mircrometer, and 2.2-mircrometer filters, colored blue, green, and red, respectively, and represents how Messier 17 would appear if the eye responded to infrared radiation. See page 1264. [The infrared picture was made with the Kitt Peak National Observatory 2.1-meter telescope by I. Gatley, D. L. DePoy, and A. M. Fowler, National Optical Astronomy Observatories, in collaboration with Charles Lada, University of Arizona]

Enclosure 3

Summary Outline of the Plan for the Future of the National Optical Astronomy Observatories

Overall: Develop, build, and operate world-class telescopes and facilities for the benefit of all qualified US astronomers. Critically evaluate existing facilities, especially as new ones come on line.

Night-time astronomy - short term:

Modernize telescopes through detectors and data processing. Permit US universities to build modern 4-meter telescopes at NOAO sites at no capital cost to the Federal Government, operate them as parts of the NSF-funded budget, and share in the observing time in proportion to financial contributions.

Night-time astronomy - intermediate term:

Construct modern 8-meter aperture telescopes, one each in the northern and southern hemispheres, for optical and infrared astronomy at the best sites (Mauna Kea, Hawaii and Chile). Both will be world-class facilities with modern instrumentation which could become parts of future interferometric arrays (see below).

Night-time astronomy - long term:

Following the national program to evaluate the capabilities, limitations, and technologies for interferometric arrays of optical/infrared telescopes, plan for such arrays in both hemispheres for unprecedented resolution (clarity of view) of astronomical objects.

Solar astronomy - near term:

Complete the GONG project which will provide first views of the inside workings of a Star, our Sun. Modernize telescopes through detectors and data processing.

Solar astronomy - intermediate term:

Plan for a high resolution solar telescope at a prime site, probably with active stabilization of the image and possibly in cooperation with other countries.

Enclosure 4a--Report of NSF's Committee on Optical Astronomy (Tape Committee)

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

September 7, 1988

Dr. Goetz Oertel, President
Association of Universities for
Research in Astronomy, Inc.
1625 Massachusetts Avenue, N.W.
Suite 701
Washington, D.C. 20036

RECEIVED
SEP 8 1988
AURA, INC.

Dear Dr. Oertel:

Enclosed are the report of the Advisory Committee for Astronomical Sciences (ACAST) Subcommittee on the National Optical Astronomy Observatories (NOAO) and the response of the ACAST.

We agree with the conclusion of the Subcommittee that the plan proposed in your letter is an appropriate response given existing conditions and fiscal constraints. We commend the Director of NOAO for her rational approach to a most complex and difficult situation and both of you for involving the communite through your "Dear Colleagues" letters.

The National Science Foundation authorizes NOAO to proceed with the necessary actions, as outlined in your letter of May 27, 1988, to adjust the FY 1989 programs of the NOAO to the present budget situation.

With respect to future actions, we note the heavy emphasis placed on timely completion of the GONG project, and we encourage the NOAO solar physics study to consider carefully the recommendations expected from the National Academy of Sciences' study "Solar Physics." Additionally, we note the high priority generally accorded the mirror-casting effort at Steward Observatory Mirror Laboratory and urge that care be taken to assure a smooth transition. We will work with you on the details as FY 1989 proceeds.

Again, let me thank you and the AURA Board, and Dr. Wolff and the NOAO Staff, for your efforts in developing a most responsive plan to cope with a difficult funding environment. We invite your comments on the Committee's report.

Sincerely yours,

Laura P. Bautz

Laura P. Bautz, Director
Division of Astronomical Sciences

Enclosures

RESPONSE OF THE ADVISORY COMMITTEE FOR ASTRONOMICAL SCIENCES
TO THE
SUBCOMMITTEE ON THE NATIONAL OPTICAL ASTRONOMY OBSERVATORIES

The Advisory Committee for Astronomical Sciences (ACAST) deplores the current level of funding for the National Optical Astronomy Observatories (NOAO), which seriously impacts its ability to fulfill its mission. NOAO is being operated efficiently and is a vital element of astronomy in the United States. In the face of somber economic realities, we recognize that difficult decisions must be made to reduce costs.

The cost-cutting measures proposed by the Director of NOAO and the Association of Universities for Research in Astronomy, Inc. (AURA) Board, and recognized as an appropriate response by the Subcommittee, have been carefully considered at all levels. Nevertheless, these cuts will dramatically accelerate the erosion of American competitiveness in the international astronomical community.

In particular, we recognize that:

1. the loss of the Advanced Development Program (ADP) and reduction of NOAO support for the Steward Observatory Mirror Laboratory (SOML) will imperil our long-term ability to pursue large-telescope projects which are crucial to the future of U.S. astronomy, unless alternative sources of support can be found;

2. the erosion of maintenance and lack of instrumentation funds will lead to a degradation of services offered by NOAO; and,

3. the inability to provide adequate funding for GONG threatens a unique project with profound implications for our understanding of solar and stellar interiors.

Unfortunately, while we agree that the proposed cuts cannot be avoided at this time, we cannot endorse this damaging action to U.S. astronomy.

06/03/88

GERALD F. TAPE
CONSULTANT
6717 TULIP HILL TERRACE
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(202) 463-1676
(301) 229-6264

July 11, 1988

Dr. Laura P. Bautz, Director
Division of Astronomical Sciences
National Science Foundation
1800 G Street, N.W.
Washington, D.C. 20550

Dear Dr.Bautz:

The Advisory Committee for Astronomical Sciences (ACAST) Subcommittee on National Optical Astronomy Observatories (NOAO) was asked

- to consider the program and options for restructuring developed by NOAO, and
- to advise the National Science Foundation (NSF) on the appropriateness of the plan proposed by Association of Universities for Research in Astronomy, Inc. (AURA)/NOAO.

The Subcommittee met on May 25-27, 1988, with representatives of AURA/NOAO and of NSF. The basis for our review was the proposed plan as described in Dr. Oertel's letter to you of May 27,1988, augmented by briefings and discussions with AURA/NOAO. It is important to note that the plan was strongly influenced by the limited FY 1988 appropriations available for astronomy and the FY 1989 Presidential budget.

Our report is enclosed. The Subcommittee is unanimous that, given the existing conditions and constraints, the program proposed by AURA/NOAO is an appropriate response. At the same time, the Subcommittee makes a number of points by way of observations and advice to AURA/NOAO and NSF, such as the importance of support for the GONG project and continuing viability of the Arizona Mirror Laboratory. We recognize and regret that, even under the best of circumstances, total scientific output will be reduced and NOAO's strength and leadership in telescope technology development may be eroded.

The astronomy community's goal is a vigorous and internationally-competitive national astronomical research program, including the development of advanced instrumentation and facilities. NOAO is

7/11/88

an important component of the U.S. ground-based optical program. Its actions impact not only its observatories and staff but all of U.S. astronomy. We deemed our Subcommittee to be inappropriate for consideration of the larger national goals and NOAO's role in achieving them. We urge NSF to address these questions in formulating plans for FY 1990 and beyond.

The Subcommittee wishes to express its appreciation to AURA/NOAO management and staff for its cooperation and responsiveness and to the NSF staff for support.

Sincerely yours,

Gerald F. Tape

Gerald F. Tape
Subcommittee Chairman

Enclosure

REPORT OF

SUBCOMMITTEE ON NATIONAL OPTICAL ASTRONOMY OBSERVATORIES

ADVISORY COMMITTEE FOR ASTRONOMICAL SCIENCES

JUNE 1988

Gerald F. Tape, Chairman
R. Grant Athay
Roger A. Bell
George B. Field
Theodore R. Gull
Harold A. McAlister
Jeremy R. Mould
Lawrence Ramsey
Robert Rosner

REPORT OF THE SUBCOMMITTEE ON
NATIONAL OPTICAL ASTRONOMY OBSERVATORIES
Advisory Committee for Astronomical Sciences

The Advisory Committee for Astronomical Sciences (ACAST) Subcommittee on National Optical Astronomy Observatories (NOAO) was established by the National Science Foundation's (NSF's) Division of Astronomical Sciences to advise it on certain aspects of the NOAO program. The Charge to the Subcommittee is as follows:

> "The National Optical Astronomy Observatories (NOAO), operated by the Association of Universities for Research in Astronomy (AURA), is supported by the National Science Foundation to provide a range of capabilities to the U.S. astronomical community for research in astronomy. It has become clear that NOAO must reduce the scope of its programs in order to strengthen the most essential ones and to provide flexibility to pursue opportunities. AURA/NOAO has sought input from the astronomical community and considered several options for restructuring.
>
> The Subcommittee is asked:
>
> - to consider the program and options for restructuring developed by NOAO, and
>
> - to advise NSF on the appropriateness of the plan proposed by AURA/NOAO."

The Subcommittee met at NSF Headquarters on May 25, 26, and 27, 1988. The meeting agenda, a list of Subcommittee members, and a list of principal participants are appended.

THE PRESENT SITUATION

Since FY 1984, new funds received each year from NSF by NOAO have been essentially constant; no provision for inflation has been provided. Purchasing power has declined. The Presidential plan for doubling the NSF budget from FY 1988 to FY 1993 did not materialize. Timing was such that significant program reductions have had to be made in FY 1988. The FY 1989 Presidential budget before Congress is also limiting. A reassessment of priorities was called for including planning for fulfillment of the NOAO mission over the longer term.

NOAO PROPOSED PROGRAM PLAN

The NOAO mission statement adopted by the AURA Board is as follows:

> "The mission of NOAO is to conduct world-class scientific

> investigations in exploring the universe at optical and infrared wavelengths. This includes building, operating, and conducting research with world-class facilities of a range of sizes and technical capabilities open to all U.S. astronomers; coordinating, and participating in, and often leading the technology development programs essential to all optical/infrared efforts in the U.S."

This Subcommittee endorses the NOAO mission statement. It recognizes the need for NOAO to be involved with world-class facilities and advanced instrumentation, with emphasis on user access.

The proposed NOAO plan (May 27, 1988, letter Oertel to Bautz appended) recognizes the need for difficult program curtailments to be made in FY 1988 and FY 1989 while preserving certain capabilities for undertaking initiatives in later years. Recognition is given to the advent of private funding for major new telescopes and the role NOAO could play in advancing, through cooperation and Government funding, the utilization of such facilities on a national basis.

DELIBERATIONS OF THE SUBCOMMITTEE

The first half of the Subcommittee's meeting, chaired by Dr. George B. Field, was devoted to receiving briefings by the NOAO Director and principals of the NOAO staff. Extensive discussions were held with the briefers as well as with the AURA President and several Trustees. The last half of the meeting was devoted almost entirely to deliberations by the Subcommittee with, at times, some AURA/NOAO interactions to clarify positions. The Subcommittee was pleased to have Dr. Arthur B. C. Walker, Jr., Advisory Committee for Astronomical Sciences Chairman, and Dr. Norman C. Rasmussen, National Science Board member, participate in the meeting.

The following constitutes the Subcommittee's views concerning the AURA/NOAO recommendations for "restructuring its program."

A. General

The Subcommittee was very impressed by the extensive review and analysis of the issues confronting NOAO under the present budgetary constraints. The decisions, although painful, show a thoughtful approach to coping with immediate problems while striving to fulfill NOAO's long-term mission. The Subcommittee concludes that the proposed plan is reasonable and responsive. It is essentially a "damage limiting" plan. Although some individuals may differ in detail with some of the AURA/NOAO decisions, it is not useful for this Subcommittee or NSF to micromanage. Great strides have been made in NOAO management; it should be encouraged.

B. Science

KPNO and CTIO are producing good science, both qualitatively and quantitatively. The continuing high number of research papers based upon data obtained with nighttime facilities demonstrates that those facilities continue to be operated so that quality data is routinely obtained and analyzed. Of key importance is the ever-improving power of focal-plane instrumentation at virtually all telescopes. Although this power benefits all fields of astronomy from planetary to galactic research, one conspicuous example is found in extragalactic research where, for the first time, a number of groups have recently been successful in obtaining images and spectra of galaxies with redshifts greater than 1 (corresponding to look-back times greater than half the age of the Universe) and as large as 3.2. Such observations demonstrate that at least some galaxies formed early in the history of the Universe, and detailed studies indicate that the morphology of some high-redshift galaxies is complex. Astronomers now have hard data concerning the formation and early evolution of galaxies, a subject which, until now, has been the province of theoretical debate based on various cosmological models. The instrument development programs of KPNO and CTIO have thus opened a new era in cosmology.

Another example is the newly-developed capability for large-format near-infrared imaging. This capability promises to find a number of exciting applications, including the observation of stars and galaxies through opaque clouds of interstellar dust, and spectroscopy of interstellar molecules.

In addition to providing the U.S. ground and space science communities, and the U.S. commercial and defense establishments, synoptic data on the behavior of the Sun, the NSO serves as the focus of U.S. efforts to develop state-of-the-art ground-based instruments to observe the nearest star, the Sun. In this role, the NSO has collaborated with Lockheed scientists in the successful use of adaptive optics in studies of extremely turbulent stratified fluids, and of turbulent mixing and diffusion of magnetic fields at very high Reynolds numbers; both problems are fundamentally inaccessible to experimental study in terrestrial laboratories. The NSO has been a leader in the extension of magnetic field measurements to the near infrared, allowing direct, relatively model independent, observations of magnetic field strength concentration on the Sun; these measurements are essential to our understanding of the solar magnetic field/fluid interactions ultimately responsible for the space plasma environment of the Earth. The NSO also serves as the focus of a national effort to study the interior of the Sun to unprecedented levels of accuracy by observing global solar oscillations ("helioseismology"), thereby providing definitive tests of modern theories of stellar structure and evolution, as well as possible tests of nuclear physics calculations of neutrino production and transport in the solar interior.

C. Uniqueness

1. Nighttime Astronomy

A major strength of the NOAO observing facilities is the broad range of instruments available to the observer on the larger telescopes and the availability of popular instruments on the smaller telescopes. In general, a much smaller range of facilities is available at university telescopes, and the NOAO facilities are the only ones available for many users. These instruments are well maintained and the down-time is correspondingly low. Telescopes are available in both hemispheres, allowing full sky coverage. The CTIO 4-meter is equipped with: an echelle spectrograph (the only such instrument currently available on a Southern Hemisphere telescope) for high-dispersion observations of relatively faint (V ~ 12) stars; an RC spectrograph for low-dispersion observations of fainter objects; infrared and visual photometers; an infrared spectrometer; an imaging Fabry-Perot interferometer; and cameras for direct imaging with Charge Coupled Devices (CCDs) and infrared arrays.

The KPNO 4-meter is equipped with an even larger range of instruments, including a unique Fourier Transform Spectrometer for high-resolution spectroscopy at infrared wavelengths. The 4-meter optical spectrographs can be used for multiple-object spectroscopy with the possibility of observing up to 50 objects simultaneously. In recent years numerous direct imaging projects have been carried out using CCD cameras, particularly on smaller telescopes. A very new and exciting program of direct imaging with infrared arrays is currently being performed. Prior to the availability of these arrays, the only technique of infrared imaging consisted of pointing the telescope in different directions in the sky to make observations of the various "pixels."

The availability of the IRAF(Image Reduction and Analysis Facility) programs and computers, both in domes and at the main offices, allows for very convenient reduction of the data.

2. Daytime Astronomy

The National Solar Observatory (NSO) operates several unique facilities including the McMath complex of telescopes, the Fourier Transform Spectrometer and vacuum telescope at Kitt Peak and the Vacuum Tower Telescope at Sacramento Peak Observatory (SPO). The three telescopes in the McMath complex are the three largest solar telescopes in the world. Data obtained from these telescopes have made a large, enduring impact on solar physics.

Although much of this impact occurred during the early years of Kitt Peak's operation, the development of the Fourier Transform Spectrometer has led to a second wave of exciting new results that continue to appear regularly.

The vacuum telescope at Kitt Peak provides the community with the most readily available and most widely used solar magnetograms. These daily magnetograms have been used in independent studies of magnetic field morphology and its cyclical variations over the 22-year magnetic cycle as well as providing reference data for a great number of papers involving other observations. In particular, solar observations from space, such as those carried out by Solar Maximum Mission (SMM), rely heavily on the Kitt Peak magnetograms as supporting data; and in particular the planned joint NSF and NASA-sponsored observational campaign to observe the next solar maximum will rely on these observations.

The McMath solar telescope is equipped with a 1-meter Fourier Transform Spectrometer. This instrument is used in solar, laboratory astrophysics, and atmospheric sciences studies. In the latter work, it has been used for the determination of wavelengths, energy levels, and transition probabilities for both atomic and molecular lines. Recently it has been utilized to probe the solar vector magnetic fields with the 12-micrometer magnesium lines. The McMath is the only large solar telescope capable of working in the thermal infrared.

The Vacuum Tower Telescope located at SPO is universally recognized as the world's leading instrument for solar studies at high angular resolution. Its uniqueness arises from a combination of outstanding image quality and highly developed focal plane instruments. The Tower attracts a steady stream of visiting scientists from all parts of the world, and it is finding important additional uses as a test site for new instrumental concepts and developments, including adaptive optics. The latter technology has lead to a real breakthrough in our view of the structure of compressible convection in solar surface layers, and of the interaction between highly conducting fluids and magnetic fields; the physics underlying these processes is of wide interest to both astronomers and physicists.

A new Stokes Polarimeter currently under construction at the High Altitude Observatory is designed for use on the Tower in partnership with NSO. In addition to providing high-resolution vector magnetic field data, the combination of the new polarimeter and the Tower Telescope will be used to test concepts and polarimeter design for magnetic-field measurements with the Large Earth-based Solar Telescope (LEST) facility. While other countries are working to develop facilities that will eventually be competitive with the Tower Telescope and its focal plane instruments, these new facilities will not be completed for another year. Until that time, the Tower Telescope will remain unique as the world's outstanding high-resolution instrument. However, early availability of observing time for U.S. scientists on foreign solar telescopes remains in question.

D. GONG

The NOAO Director and AURA have proposed that the NSO budget, including the GONG project, be given a fixed percentage of the NOAO budget in FY 1989 and subsequent years. They have further suggested that a committee be formed, under the leadership of Dr. John Leibacher, to decide how to allocate these funds between the GONG Project and SPO, Kitt Peak, and Tucson operations. It is recognized by NOAO and AURA that the funds allocated by NSF are insufficient to carry out the GONG Project if the SPO and Kitt Peak facilities are operated at their current level. As the GONG Project ramps up to its required level, facility support will necessarily diminish unless NSF provides an appropriate incremental funding wedge.

GONG was planned and brought to funding level through the combined efforts of a broadly-based community of solar astronomers plus a number of astrophysicists not traditionally thought of as having mainly a solar orientation. Because of these circumstances, the GONG Project is not seen by the community as being either a strictly solar project or as a strictly NSO project. It does not appear proper to the Subcommittee, therefore, that the GONG Project be jeopardized by placing it in direct competition for funds with the SPO and Kitt Peak facilities of NSO. Failure to complete the GONG Project after enlisting the enthusiastic support of the community and expenditure of considerable effort would reflect badly on the entire NOAO. It is recommended that the GONG Project continue to be funded at a level sufficient to ensure its continuation to a successful and timely conclusion. In our opinion, this should be the highest priority for the NSO during the next few years.

The question of how to best use the remaining funds available to NOAO to support one or both of the SPO and Kitt Peak sites is properly left to an appropriate NSO committee. Membership of such a committee, however, should include individuals external to NOAO. Particular attention should be paid to the guidelines established by the forthcoming report of the National Academy of Sciences' Committee on Solar Physics.

E. Upgrading National Capabilities

The survey of the optical/infrared astronomy community by AURA showed clearly that NOAO plays two important roles: provider of a steady stream of astronomical data to its users; and a builder of new facilities to open up new areas of astronomical research. NOAO has proposed an imaginative scheme to play both roles: the new NOAO Program Description proposes "to undertake the evolution of CTIO and KPNO from smaller to larger telescopes through collaborations with universities." The Subcommittee wholeheartedly endorses this goal and steps along this road, such as the WIN 3.5-meter telescope project.

As NOAO has pointed out, and both the Greenstein and Field Committees recommended, telescopes of the 4-meter class are likely to become the workhorses of the future that 1-meter to 2-meter telescopes are now. There are three main points here:

1. For some applications, 4-meter telescopes are as cost effective as larger ones. Examples of such applications are redshift surveys of galaxies and long-slit spectroscopy.

2. Some large projects are impeded more by competition for observing time than lack of aperture. Examples of such projects are synoptic observations and targets of opportunity.

3. Techniques such as multiple-object spectroscopy can use sophisticated instrumentation to compete with large telescopes provided the smaller telescope is also operating in the background (sky) noise limited regime.

Participation by NOAO in university consortia makes for effective cooperation because the universities have a unique ability to raise private and state capital for new projects, while NOAO can contribute operational efficiency, stability, and a developed site. All parties can contribute expertise necessary to make advanced projects viable. The Subcommittee enthusiastically endorses the first such proposed joint venture by NOAO with the advice:

1. that it must insist on community access to the telescope commensurable with NOAO's and NSF's investment in the project;

2. that NOAO must seek to build a telescope with a genuinely low maintenance cost in order to validate the claim of replacing older, small telescopes with larger ones without disenfranchising the greater user community; and,

3. that NOAO must not lose sight of its, and NSF's, long-term goal to provide community access to an optical/infrared telescope as large as that of any university or international consortium.

F. A NOAO 8-Meter-Class Telescope

Although seriously constrained by budget, the proposed NOAO plan presents a feasible path to the development of the large-aperture telescopes that will be needed for it and the user-oriented community to be scientifically competitive at the end of this century. A thoughtful program to produce and evaluate a 3.5-meter BSG (BoroSilicate Glass) mirror culminates in an observing facility such as the WIN project. At the same time, it lays the groundwork for an 8-meter-class instrument. This approach allows NOAO to keep the future in sight while still satisfying most of the current scientific needs of the user community. It is, however, not without some risks to both NOAO and the next generation of NOAO users who will have to compete scientifically with astronomers worldwide and in the U.S. with access to larger telescopes. NOAO should not become so preoccupied with the collaborative building of 4-meter-class facilities and maintaining smaller telescopes, both at KPNO and at CTIO, so as to lose momentum toward an 8-meter-class facility. The time scale for the completion of the first 4-meter initiative (WIN) coincides with the projected time scale for the first large ESO and U.S. telescopes. In addition, at least one other U.S. consortium should be well underway by then. In such a climate, it could well be difficult for NOAO to gather the support and make the sacrifices required to secure funding and implement a national 8-meter program.

Withdrawal of direct NOAO support of the Steward Observatory Mirror Laboratory (SOML) carries with it the danger of leaving the impression that NOAO is backing away from a commitment to build a large telescope. The Subcommittee strongly endorses the recommendation of the AURA Future Directions Committee that NOAO should be "developing world-class optical and infrared facilities and innovative instrumentation." As such, it urges NOAO to aggressively pursue funding for an 8-meter telescope from both public and private sources as well as maintain a highly-visible role in the current and developing large-telescope consortia. NOAO should recruit as expeditiously as possible a Principal Investigator for the 8-meter project.

It is unfortunate that the NOAO is put into such a situation that it must withdraw support from the SOML literally on the eve of its first large success. This program represents the best possibility for significant U.S. national participation in large-aperture telescopes. The possibility that private resources can come to the rescue is recognized, but the failure of such resources to materialize could have severe impact on the future of large-telescope development in the U.S. We strongly urge that NOAO, NSF, and the community work with the SOML to see that the resources are available to continue expeditious progress toward producing 8-meter BSG mirrors. Indeed, without such a commitment, it may well prove difficult to secure the private resources needed to proceed.

G. Advanced Development Program

The Advanced Development Program (ADP) was established as a division of the NOAO charged with the exploration of new technology and instrumentation having future applications throughout the observatories. The ADP successfully recruited an exceptionally talented staff that identified a number of areas with strong near- and long-term payoffs for U.S. astronomy. The Future Telescope Technology Program (FTT) has pursued problems critical to the development and deployment of telescopes using 8-meter mirrors, including the support of the borosilicate glass honeycomb mirror project of the University of Arizona. The ADP Advanced Concept Exploration Program (ACE) has developed an adaptive optics system, defined a concept for a distributed optical array for very-high-angular-resolution imaging and developed certain hardware prototypes of key aspects of an array, built an infrared speckle imaging system soon expected to be user-qualified, and pursued other techniques with promising future applications at the largest telescopes. The ADP has accomplished a great deal since its inception in spite of the inability of NOAO to provide it with a budget fully supportive of its programmatic goals. A well-funded ADP is clearly a basic element of a healthy national observatory.

NOAO and AURA now recommend the elimination of ADP as a division. Accompanying the discontinuation of ADP is the closing of the gratings laboratory, the elimination of the distributed array project, and the halting of the adaptive optics effort at its demonstration stage. The FTT effort will be scaled down with the goal of working toward the completion of a proposal for 8-meter telescopes to be submitted late this year. NOAO will attempt to maintain the capability previously found within ADP to improve and develop instrumentation for existing telescopes.

The elimination of the ADP Division and the resulting drastic curtailment of NOAO support of activities intended to benefit future U.S. astronomy are considered by NOAO and AURA as preferable to their continuation at a less-than-subsistence level, or to the closing of most of the present night-time telescope facilities. NOAO proposes that certain of the ADP activities, such as adaptive optics, be incorporated into the 8-meter telescope proposal and point out that other programs, such as the distributed array, are being pursued by some universities. Nevertheless, with the elimination of its Advanced Development Program, NOAO is sacrificing much of its ability to provide leadership to the future directions of ground-based optical astronomy. This is a substantial diminishment of the ability of NOAO to fulfill its complete mission in support of U.S. astronomy. NOAO is left with a "chicken-and-egg" problem. Without a commitment to a major project, senior staffing is difficult and without project leadership, commitment is unlikely to be forthcoming.

Seeing no alternative short of the closing of NOAO facilities actively and extensively now in use by the astronomical community, this Subcommittee supports with regret the NOAO/AURA recommendations with respect to the Advanced Development Program.

SUMMARY

The ACAST Subcommittee on National Optical Astronomy Observatories has considered the program and options for restructuring in the light of NSF interpretation of fiscal constraints imposed by the FY 1988 Congressional appropriation and the FY 1989 proposed Presidential budget, and as developed in response to these by NOAO. The implications of this restructuring for the health of a national ground-based astronomy program and for the role to be played by NOAO need to be addressed in a larger context than was possible in this review. The Subcommittee does, however, endorse the NOAO mission statement that includes ". . . world-class facilities of a range and of sizes and technical capabilities open to all U.S. astronomers . . . ."

The Subcommittee is unanimous in advising the NSF that the plan proposed by AURA/NOAO is an appropriate response, given existing conditions and fiscal constraints. The Director of NOAO is to be commended for her rational approach to a most complex problem.

The Subcommittee makes the following points by way of observations and advice to AURA/NOAO and to the NSF Astronomy Division Director:

1. Upgrading of ground-based observing facilities is needed. The move toward upgrading with new 4-meter-class telescopes is timely as is the possibility of private funding, especially for construction. NOAO should continue to explore joint projects that will combine private and Government talent and funding to serve national astronomy needs. The WIN Project is such an example. NOAO participation in such arrangements should not be so extensive as to interfere with its even-longer-term objectives.

2. For the longer term, construction of at least one 8-meter-class telescope should be a NOAO priority objective. Participation in construction and operation of 4-meter-class instruments will provide experience and staffing for undertaking development of a larger instrument. An early commitment to an 8-meter-class telescope is required of both NOAO and NSF.

3. To achieve the foregoing objectives, continuing operation of the Steward Observatory Mirror Laboratory is necessary. A coordinated commitment and plan involving NSF, NOAO, interested private organizations, and the University of Arizona are required.

4. The GONG Project was established through the combined efforts of a broadly-based community of solar astronomers and astrophysicists. The Project should continue to be funded at a level to insure its continuation to a successful and timely conclusion.

5. The proposed NOAO Committee to develop a long-term program for solar physics within the NSO should be broadly based and include external members. Particular attention should be paid to the guidelines established by the forthcoming report of the National Academy of Sciences' Committee on Solar Physics.

6. Successful and effective pursuit of a national ground-based astronomy program requires cooperation and coordination by all parties, private and public, in order to obtain the maximum scientific return on the total national investment. NSF has a major leadership role in establishment and support of the federal component. NOAO is an important part of that element.

7. The Subcommittee commends the AURA/NOAO management and staff for its responsiveness and planning. The reductions are the consequence of inadequate funds, not inferior science or excessive support or overhead. AURA/NOAO management has been attentive to community needs and effective operations.

ASSOCIATION OF UNIVERSITIES FOR RESEARCH IN ASTRONOMY, INC.

SUITE 701
1625 MASSACHUSETTS AVENUE, N.W.
WASHINGTON, D.C. 20036
202-483-2101

Goetz K. Oertel
President

May 27, 1988

Dr. Laura P. Bautz, Director
Astronomy Division, MPS
National Science Foundation
1800 G Street, N.W.
Washington, D.C. 20550

Dear Dr. Bautz:

This letter will serve to outline the process followed by NOAO and AURA to review the programs supported within the National Optical Astronomy Observatories and to reduce the scope of activities to correspond to the funding level requested by the President in the budget submitted to Congress for FY 1989. Specific recommendations for the program for FY 1989 and beyond are also provided. A mission statement for NOAO is attached.

As you are aware, new funds received from the NSF by NOAO have been essentially constant, with no adjustments for inflation, for the five fiscal years 1984-1988. The increase in the CPI index for Tucson during this time has been 20%. Despite the effective overall decrease in support for the observatory, all programs have been continued, and a major project (GONG) has been initiated. The budget has been balanced each year through such steps as salary freezes, reductions in staff, deferral of facilities maintenance, and reducing support for focal plane instrumentation.

For FY 1989 maintaining the current level of effort, providing for increases in costs of insurance, and incrementing the GONG budget by $0.5M, as called for in the NSF plan, require 10% or $2.4M more than requested in the President's budget. It is the view of AURA and NOAO management that it is no longer possible to continue to operate all of the programs now in place within NOAO, and that some programs must be eliminated or greatly reduced in scope in order to match NOAO program requirements to the budget request.

The budget situation has been outlined in more detail in two letters sent to members of the astronomical community. These letters are attached, and responses from the community were one factor in determining the recommendations that are being made to you. In addition, the Associate Directors of NOAO for the Advanced Development Program, CTIO, KPNO, and NSO were asked to prepare an analysis of the programs within their divisions, to evaluate their scientific productivity, and to make recommendations of priorities in response to a budget cut of 10 percent. This material has been presented to the Subcommittee of ACAST that was set up to review the AURA recommendations. The Subcommittee, along with members of the AURA Board also heard oral presentations by the NOAO Director and Associate Directors.

Following this joint meeting, AURA accepted and endorsed NOAO's recommendations for restructuring its program. The actions to be taken and corresponding budget reductions are as follows:

1. General Budget Reductions $400,000 ($26.40M Funding Level)

Eliminate KPNO senior scientific position, eliminate support for page charges and travel for visiting observers, eliminate support for the light pollution program, reduce support for central administrative services and for the Tucson headquarters building.

Travel support would be provided only for thesis students working on doctoral research and, at the Director's discretion, for scientists who cannot obtain other funding.

2. Eliminate the Advanced Development Program $459,000 ($25.94M)

Gratings laboratory would be permanently closed; support for the prototype interferometric array would stop; a scientific staff position in interferometry would be eliminated, as would an engineering position in the FTT program.

3. Mirror Program Phase Out $275,000, FY 89; $1,100,000, FY 90
($25.67M, FY 89; $24.84M, FY 90)

Maintain NOAO support for the Steward Observatory Mirror Laboratory only through June 1989. This will save $275,000 in FY 1989 and $1,100,000 in FY 1990. NOAO still considers the Honeycomb Mirror to be the primary option for 8-meter telescopes, but it currently has no approved 8-meter telescope project.

4. Temporary Measures in FY 1989 $1,270,000 ($24.4M)

Defer facilities maintenance and computer purchases, freeze non-payroll spending at FY 1988 levels, and freeze vacant positions. At this level the budget is reduced to the President's request for FY 89.

5. Solar Program

Work with Solar community to develop a long term program for solar physics within NSO that provides for a viable NSO under various assumptions. The scope of this study covers the NSO facilities and the GONG. This plan would be implemented in early calendar year 1989 to meet the level of funding provided within the President's budget request to Congress for FY 90.

6. Telescope Closure

In the summer of 1989, one 0.9-m telescope at KPNO will be closed. Funds saved, which are estimated to be between $50,000 and $100,000 will be used to improve the optical instrumentation program at Kitt Peak.

7. Other Issues

Steps that were considered and not recommended because of their severe impact on the science and on the user community were closure of 4 telescopes at CTIO, which would save an additional $400,000 and immediate closure 4 telescopes at KPNO, which would save $500,000; we also considered but do not recommend holding GONG at its current funding level of $1,000,000; the program plan for FY 1989 will recommend increasing funding for this project to $1,500,000. In spite of their consequences for Science and the user community, one or more of the above steps would be necessary if the NOAO budget level falls significantly below the President's request level of $24.4M.

The primary consideration in arriving at these recommendations was the quality of the science, which was viewed as being more important than number of publications, size of telescope, or uniqueness of a particular facility or instrument. It is also our view that whenever possible, NOAO should purchase, rather than develop, telescopes, instrumentation, and specific technologies. It is also important to provide an orderly transition period for those programs for which funding is to be reduced or phased out.

AURA further recommends that the balance between solar and nighttime astronomy be maintained at the level of the FY 1989 program plan, which will be submitted to the NSF later this summer. Based on AURA's assessment of the scientific opportunities and requirements of these two areas of research, additional relative increases in funding for solar programs are not warranted.

AURA feels that it is essential that this budget reduction be coupled with a clear commitment by the NSF to strong national observatories, including new observing facilities and instrumental capabilities so that NOAO facilities will remain competitive with the finest facilities in the world. Accordingly, AURA places high priority on the early completion of a proposal to construct two 8-m telescopes and on seeking partial funding for this project through sources outside the NSF. In addition, AURA plans to join with universities to jointly construct and operate at least one additional 4-m telescope at CTIO and KPNO. This effort will be carried out within a level of effort budget by using university funds for construction and by closing smaller NOAO telescopes and reprogramming operating funds to new facilities.

A number of hard choices have been made in preparing these recommendations. The Advanced Development Program and especially the NOAO effort to develop interferometric techniques have been eliminated. In deferring its further funding for the mirror casting program to the 8-m size, AURA recognizes that its aspirations to build 8-m telescopes will be delayed until project funds are authorized, and that construction of 8-m telescopes will rely in part on technology developed by other groups. NOAO will work closely with Steward Observatory to help make the mirror program successful and productive. A long range plan, which takes into account realistic estimates of likely funding levels, is also needed for the National Solar Observatory. The new director of NSO will be charged with preparing such a plan by early in calendar year 1989, and this plan will guide NOAO's program in solar physics.

We believe that these steps are as responsive as possible to the needs of the community, given the constraints placed on NOAO by the funds provided. We hope that you will accept these recommendations and authorize NOAO to proceed with the necessary actions.

Sincerely,

Goetz K. Oertel

Goetz K. Oertel

MISSION STATEMENT OF NOAO

The mission of NOAO is to conduct world-class scientific investigations in exploring the universe at optical and infrared wavelengths. This includes building, operating, and conducting research with world-class facilities of a range of sizes and technical capabilities open to all U.S. astronomers; coordinating, and participating in, and often leading the technology development programs essential to all optical/infrared efforts in the U.S.

MEMBERSHIP LIST

SUBCOMMITTEE ON NATIONAL OPTICAL ASTRONOMY OBSERVATORIES

Dr. Gerald F. Tape (Chairman)
Former President
Associated Universities, Inc.

Dr. R. Grant Athay
High Altitude Observatory
National Center for Atmospheric
Research

Dr. Roger A. Bell, Director
Astronomy Program
University of Maryland

Dr. George B. Field
Center for Astrophysics

Dr. Theodore R. Gull
NASA/Goddard Space Flight Center

Dr. Harold A. McAlister
Center for High Angular
Resolution Astronomy
Georgia State University

Dr. Jeremy R. Mould
Division of Physics, Mathematics,
and Astronomy
California Institute of Technology

Dr. Lawrence Ramsey
Department of Astronomy
Pennsylvania State University

Dr. Robert Rosner
E. Fermi Institute and Department
of Astronomy and Astrophysics
University of Chicago

ADVISORY COMMITTEE FOR ASTRONOMICAL SCIENCES (ACAST)

SUBCOMMITTEE ON THE NATIONAL OPTICAL ASTRONOMY OBSERVATORIES (NOAO)

TENTATIVE AGENDA

Wednesday, May 25, 1988

09:00	Introductory Remarks (Tape, Bautz)
09:15	Opening Remarks (Oertel)
09:30	Overview (Wolff)
10:00	Divisional Programs ADP (Beckers) CTIO KPNO (DeYoung) NSO (Leibacher)
12:00	Lunch
01:30	Science at NOAO Quasars (Osmer) Infrared (Gatley)
03:00	Budget details-Options-Implications
05:00	Adjourn
06:30	Dinner

Thursday, May 26

Closed Session

09:00	Proposed NOAO Plan (Wolff, Staff)
1:30	Committee Discussion
05:00	Adjourn

Friday, May 27, 1988

Closed Session

09:00	Committee Discussion
01:30	Committee Recommendations to NSF
05:00	Adjourn

ADVISORY COMMITTEE FOR ASTORNOMICAL SCIENCES
SUBCOMMITTEE ON THE NATIONAL OPTICAL ASTRONOMY OBSERVATORIES

LIST OF PARTICIPANTS

NSF

R. Nicholson
L. P. Bautz
K. W. Riegel
S. L. Tuttle
C. M. Kellett
D. G. Wentzel
F. J. Giovane
D. Peacock
A. Asrael
J. Lasken
K. Wilson

NSB

N. Rasmussen

ARIZONA

R. Angel

NOAO

S. Wolff
D. DeYoung
P. Osmer
J. Beckers
T. Gatley
J. Leibacher

AURA

R. Noyes
G. Oertel
B. Peterson
C. Anguita
K. Honeycutt
R. Rossi
R. MacQueen
R. Zdanis

ACAST

A. B. C. Walker, Jr.

bcc: Goetz Oertel

Enclosure 4b--Letter from Mr. Harry Albers to Dr. Warren Baker of the National Science Board

San Diego State University
FOUNDATION
San Diego, CA 92182-1900

SDSU

RECEIVED
JAN 30 1989
AURA, INC.

January 24, 1989

Dr. Warren J. Baker, President
California Polytechnic State University,
San Luis Obispo
San Luis Obispo, California 93407

Dear President Baker:

Thank you for taking the time to discuss astronomy matters at the recent meeting of Trustees. While I have not yet seen the agenda materials for the Committee on Programs and Plans, I did want to set down the thoughts regarding the NSF budget that are uppermost on the minds of those involved with the management of the nation's optical observatories. As Vice Chair of the AURA Board I have been involved in extensive discussions on these matters with Goetz Oertel, President of AURA and Sidney Wolff, Director of NOAO.

Background

Discoveries in astronomy are changing our view of the universe at a pace that has not been matched since the time that Galileo first turned his telescope to the heavens. The key to the rapid advance is the opening up of new wavelength regions by building space observatories. During the next decade the NASA great observatories will provide capabilities in the gamma-ray, x-ray, ultraviolet and infrared regions of the spectrum.

It is the nature of astrophysical processes, however, that much of the significant information content about abundances, dynamics and physical conditions is found in the ground-based optical region of the spectrum. High energy processes are well studied in the radio. Both of these areas are the traditional province of the NSF, and progress in astronomy depends on having improved capabilities in those wavelengths tnat are observed from the ground as well as from space.

The pace of discoveries, of new insights and of innovative technology development continues to accelerate. Astronomy attracts the very best scientists and engineers; astronomy is uniquely effective in attracting young people into technical careers; legions of Americans are involved in astronomy as amateurs, through the media and through planetariums; and astronomy is deeply connected with human culture through philosophy and religion. Nevertheless, astronomy has fared poorly at NSF where the budget for astronomy has been level since 1984. No new telescopes have been built for 15 years except in radio astronomy. Because of the increasing scope of astronomy, individuals and observatories have fared even worse. For example, the National Optical Astronomy Observatories (NOAO) have seen their budget decline in real terms every year for the past decade. Telescopes have been shut down and new developments discouraged or curtailed. Grant funds are so scarce that NSF must decline support for better and better proposals. From my own experience as a board member of AURA and as a former director of administration at NOAO (in significantly better budget times) I can vouch for the fact that NOAO could not be running a more competent or leaner organization. In fact, it is lean to the point of being unhealthy.

The just released NSF budget for FY 1990 continues the trend. NSF funding is up by 14%, astronomy funding barely covers inflation at 4% and individuals and centers will get even less. Mothballing and/or closing of facilities is a certainty at this level.

Meanwhile, Europe's industry has convinced the governments of the nine member countries of the European Southern Observatory (ESO)to invest $225 million in four new optical telescopes, each one with four times the collecting power of our largest national telescope. One of their main arguments is that the project will train people and make Europe's industry more competitive.... Incidentally, their facilities already eclipse the U.S. facilities in numbers of telescopes and in funding per telescope. American ingenuity has helped us keep up through significant technology advances which make our smaller telescopes more powerful, but ESO will soon use the same technology on even larger and more modern telescopes.

What To Do

An aggressive rejuvenation initiative could be funded if the NSF astronomy division's budget increases on the same time scale as is projected for the overall Foundation budget. Such an initiative could include at least one world-class optical and one new radio telescope; it would strengthen the technology base for astronomy of the future and it would benefit U.S. astronomers through grants and through access to modern telescopes. The national program could regain the lead, or at least be competitive internationally. Even then, astronomy's share in the Foundation's budget would be less than it was a decade ago. The NSF should "buy into" a revitalization of ground-based astronomy in general, and into a specific set of plans for the national centers. While there will be fluctuations in the budget from year to year because of the political process, some statement of commitment to a set of goals would be invaluable in AURA's/NOAO's planning. With an annual budget cycle and no advance information about funding status and priorities from NSF it is extremely difficult to know whether to plan for increased funding, which leads to one set of priorities, or to continued budget erosion, which leads to another. If the organization guesses wrong, then the programs are far less effective than they might be.

Specifically

A rejuvination initiative to revitalize the NSF astronomy program should include:

- At the top level of NSF, commit to the National Centers in Astronomy:
  - to their missions, goals and objectives
  - to keep them viable with stable base support
  - to embrace their long range plans in principle
- Follow through on projects such as the Global Osallation Network Group (GONG) program.
- Start critical initiatives recommended in the last Astronomy Survey (commissioned by the NSF and NASA and operated by the National Academy), such as two 8-m optical telescopes for the northern and southern hemispheres, and fund such initiatives separately as "add ons" to the base budget.
- Develop critical technologies to explore and define options for the Astronomy Survey, such as
  - interferometric arrays (of telescopes)
  - single mode optical fibers (for arrays)
  - arrays of detectors (CCDs)

As "guardians" for the national optical astronomy centers and as a leading voice for the nation's astronomers, AURA and NOAO are determined to see that these goals are accomplished and we plan to continue to voice our concerns, exasperations and hopes. The Committee on Programs and Plans can do much to help in this matter.

Thank you for your interest and assistance.

Sincerely,

Harry R. Albers

Harry R. Albers
General Manager

HRA:dg
cc: President Day

Enclosure 5

Value of Astronomy for Science and Technology

Science:

- Astronomy shows matter under extremes of temperature, density, magnetic and electric fields, etc.
- Elementary particle physics and cosmology become intimately inter-related in the study of the first instants of the universe.
- Explaining what we observe in the universe places the most challenging demands on our understanding of the laws of nature.
- Astronomy borders on virtually all other mathematical and physical sciences and impacts them as they impact astronomy.

Technology:

Astronomy

- employs all conceivable remote-sensing detector technologies
- demands extremes of sensitivity, quality, effectiveness
- requires combinations of detector and computer technologies
- pushes technologies better performance and higher quality

Education:

Astronomy

- attracts people into science and technologies
- illustrates the value of science in understanding nature
- captures the imagination of experts and laymen alike
- is intimately connected with history, culture, civilization
- relates to religion, philosophy, and our place in the universe

The following letter from Mr. Ken Willcox, President of the 10,000 member Astronomical League, a federation of (amateur) astronomical societies, documents the importance of astronomy in drawing people into technical careers.

ASTRONOMICAL LEAGUE

A FEDERATION OF ASTRONOMICAL SOCIETIES
A NON-PROFIT ORGANIZATION

- ★ *To promote the science of astronomy.*
- ★ *To encourage and coordinate activities of amateur astronomical societies.*
- ★ *To foster observational and computational work, and craftsmanship opportunities in the various fields of astronomy.*
- ★ *To provide a medium for correlating amateur activities with professional research.*

SCIENCE SERVICE BUILDING
WASHINGTON D.C. 20036

March 2, 1989

Please reply to:

Ken Willcox, President
225 S.E. Fenway Place
Bartlesville, OK 74006

Senator Robert C. Byrd
SH-311 Hart Senate Office Bldg.
Washington, D. C. 20510-4801

Dear Senator Byrd,

As President of the Astronomical League, I represent over 10,300 amateur astronomers throughout the U. S., and as a research chemist for Phillips Petroleum Company, I owe my career in polymer chemistry to astronomy. There is no branch of science that offers greater appeal to young Americans to pursue a technical or scientific career. Having had the opportunity to discover the universe at an early age, I realized that there were many areas of science that interested me. This experience is shared by many of my fellow amateur astronomers and illustrates that astronomy's impact reaches far beyond the traditional astronomical community. We share observational results with them, and we consider ourselves part of the broader community of astronomers. It is our desire that you consider the outstanding and unusual breadth, depth, and effectiveness of astronomy's impact on education and science in your deliberations on the future of NSF support for groundbased astronomy at our national centers and universities. Without adequate financial support for observational astronomy, the emphasis we so desperately need for science education in our country will suffer further defeat.

Phillips Petroleum Company sponsors an annual science teachers workshop for over 300 elementary and secondary science teachers that addresses every area of science. Each year, the one subject more teachers show interest in than any other is astronomy. They intuitively know that by understanding this subject better, they can attract the students that would most likely choose a career in science. Most high school students and many college students do not know what they want to be because they have not had the opportunity to discover the fascination of the universe. By lending support to astronomical research, our government will provide the necessary foundation on which our country can grow technologically.

The greatest benefit is without doubt to our nation's young people who, right now, more than ever before in the history of our nation, need something to focus their attention on rather than drugs and TV. None of us can save the world singlehandedly, but by offering alternatives to our young people such as astronomy, which has such an appeal, I intend to save as many as the good Lord will allow me.

Sincerely,

Ken Willcox

Enclosure 6

Wide Recognition of Merits of Astronomy

o The widely read popular science literature abounds with astronomy articles and news. So do newspapers and magazines.

o On the bestseller list is one of the best science books ever: "A brief history of Time" by Steven Hawking, a victim of Lou Gehrig's disease, and today's occupant of the professorship once held by Isaac Newton. The book covers the most esoteric concepts of modern astrophysics and cosmology and discusses their meaning.

o Hundreds of thousands of Americans are amateur astronomers, organized in several national societies and in countless astronomy clubs.

o Astronomy is unique among the physical sciences in that amateurs can and do contribute regularly, systematically, and significantly to research including through observations of variable stars, and more spectacularly through the discovery of comets and of supernovae in distant galaxies outside our own.

o Every year, Americans attend sessions at the 1,000 US planetariums throughout the land. The most popular may be the National Air and Space Museum planetarium in Washington with 400,000 visitors annually.

o Astronomy is covered extensively by newspapers throughout the land. A recent editorial "America Ignores Astronomy at its Peril" by John Wildenthal, a Houston municipal judge, in the January 9, 1989 Houston chronicle follows:

Outlook Items on this page do not necessarily reflect the opinions of the Houston Chronicle.

Page 2 of 2 Price to Oertel

America ignores astronomy at its peril

JOHN WILDENTHAL

N the push to keep the United States from falling behind in the race to produce scientific advances, Americans are neglecting a fun- nental science.

stronomy has furnished the keys that have ocked the treasures of the other sciences ich, in turn, have produced rewards beyond imagination of the astronomers who pro- ed the keys.

ndeed, humanity's first big step from the nting civilization to agriculture could not have ceeded without astronomy. The astronomers ovided the calendar. That solved the problem knowing when to plant the seed saved from previous crops so that the precious seed uld not be wasted and lost in so-called Indian nmers or false springs.

ust as agriculture could support and bring ssings to millions more people than the hunt- civilization ever could have supported, so n today's science and technology bring health d well-being to millions more than pre-Coper- an agriculture ever could have supported.

The astronomy of Copernicus was the key that locked the treasures of the modern sciences. e "Copernican Revolution" is the right name the great awakening. Copernican astronomy ggered the physics and chemistry which are heart of modern sciences.

As to physics, Sir Isaac Newton's work, begin- g with his concept of gravity, grew out of one eat insight. He realized the elliptical orbits of anets are like the trajectories of objects falling Earth. They are caused by the same force, avity. Philosophers and theologians had de- ared unanimously that the orbits of planets are rfect circles because this is a perfect universe. ewton would never have known about the ellip- al orbits if astronomers had not observed and easured them.

Thus astronomy: 1) destroyed the illusion of a at Earth; 2) gave Newton the key to unlock the easures of physics; and 3) established that sci- tific information comes from observing and easuring things rather than from the untested ntemplation of philosophers and theologians.

As to chemistry, astronomy not only liberated at science from the grip of the philosopher and eologian but also furnished the concept of nall objects (planets) orbiting around a big cen- al object (the sun), thus giving currency to a odel for the chemist to understand the atom as nsisting of electrons orbiting around a nuclear rticle.

Astronomy has continued to be a laboratory r physics and chemistry, most notably in deter- ining the speed of light, in the development of alytic spectroscopy, and in connection with lbert Einstein's physics.

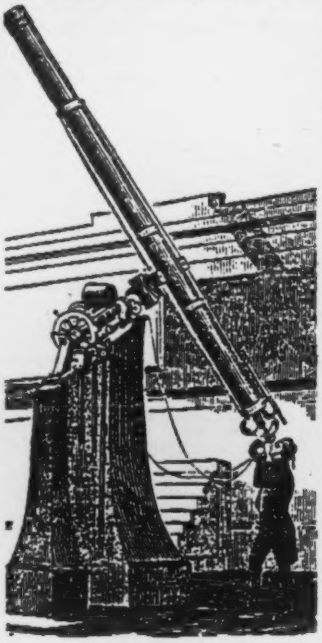
Why should we expect that astronomy can yet roduce revolutionary new discoveries? Astron- mers know they have barely scratched the sur- ice of what there is to be observed. For one ing, energy-release mechanisms can be seen hich appear much more powerful than can be explained satisfactorily by today's science. More observatories with much more powerful instruments are needed to pursue these mysteries.

Wildenthal, a municipal judge for the city of Houston, is a member of the Board of Visitors of the McDonald Observatory and Department of Astronomy of the University of Texas at Austin.

Can anyone seriously believe that "intelligent" life on a planet so tiny, so immeasurably minute, could be expected to survive without studying and making use of the universe around us? While few, if any, religious congregations do open battle against Copernican astronomy today, is it the attitudes of the religious communities in America that are causing this country to neglect the study of our universe?

Logically, those of us who believe that a benign and loving God created our gigantic universe should be taking the lead looking for blessings from God's enormous creation. But it is "churchgoing" America that is lagging behind.

For several decades, the "godless" Soviets have had enough faith in God's creation to invest in building and operating the world's biggest telescope.



The Europeans, whose churches are mostly empty every Sunday, have enough faith in God's creation to be building the first observatory of the kind now needed. It is being constructed in northern Chile where many mountain peaks are available to provide better viewing than anywhere else on the globe. It will consist of an array of four giant telescopes. Each will be nearly the size of the giant telescope which the Keck Foundation is funding for Cal Tech and the University of California to build on a mountain in Hawaii. Japan is also preparing to build in Hawaii a trail-blazing giant telescope originally designed by the University of Texas, we Texans having lost our project when oil prices fell.

America's astronomy program, which was at its best during the height of the space program, was meager even then. Only Texas and California give meaningful state support to astronomy, and that support compares poorly to what we and the Californians spend to pick up beer cans off our highways.

Our orbiting telescope has such a low priority that its launching date is yet to be firmly set. It will provide the sharpest views yet of the universe as well as unique information at wavelengths where the atmosphere blocks the view c ground-based telescopes. More orbiting telescopes are urgently needed. Each could keep a dozen ground-based observatories busy because the orbiters will identify objects that also emit radiation at wavelengths which can then be stuc ied much more economically and efficiently on the ground.

To argue that private philanthropy and the government should not be investing in astronomy until we can overcome poverty and human need would be like arguing that we should not i vest in manufacturing antibiotics until we've spent the money it takes to cure pneumonia. How many millions of people are we dooming t suffer and die because of today's ignorance — because we are postponing the knowledge and blessings that astronomy can bring for humanity?

Yes, it's tough to find either gifts or tax mone for astronomy in times like these. We can imag ine it must have been similar in prehistoric times. When human population began pressing the limits of game available for hunting, the tribal elders must have felt that the stargazers should be getting a good night's sleep so they could help the tribe get a better share of the increasingly scarce game. Perhaps there was someone like former Sen. William Proxmire, D Wis., giving something like a Golden Fleece award to the wastrel stargazers.

Unlike the tribal elders, we know from exper ence that astronomy produces enormous blessings previously undreamed. To wonder about t future of astronomy is to be like a child wonde ing what Santa Claus will bring for Christmas. But how distressing it is to see that so little is b ing done today, particularly in America. Surely we can put more into astronomy than we spenc picking up beer cans.

Enclosure 7

Relationship between Groundbased and Space Astronomy

Space astronomy offers freedom from obscuration and distortion by the Earth's atmosphere and from stray light and other effects of civilization, however, space missions are few and far between, cost a lot, require decades of planning and preparation, depend upon a complex infrastructure, and are difficult to modernize once launched.

Groundbased observatories are affected by the atmosphere but are less costly to build and operate: a modern groundbased telescopes the size of the Hubble Space Telescope can be built for 'only' about $10M.

Groundbased and space observatories therefore complement each other: it is cost-effective to reserve space telescopes only for studies which cannot be done from the ground.

Groundbased and space telescopes also complement each other in other ways: some objects look superficially no different to groundbased observers than do billions of stars or galaxies but turn out to be very special or unique when viewed from space. Once identified, such objects can be studied extensively from the ground to understand and explain their nature, or to define how to best use precious space telescope time to follow up.

All Federal funding for groundbased observatories comes from the NSF. NASA funding for the support of space mission such as theory and data analysis excludes support for related groundbased observations. (Exception: NASA's planetary program).

Enclosure 8

Comments on European and US Programs in Groundbased Astronomy

1. The European Southern Observatory (ESO)

ESO has established an observatory in Chile which

- o operates twice as many telescopes as NOAO's Cerro Tololo Inter-american Observatory
- o spends twice as much per telescope as does NOAO
- o will be the site of four new 8-meter telescopes, the equivalent of a 16-meter telescope, called the Very Large Telescope (VLT).

The nine member nations of ESO together have firmly committed more than $200M to build the VLT, the world's largest telescope.

Interest in competitiveness in science and technology has, in part, motivated ESO: its Director General has stated that industry in the nine member nations worked hard to convince their respective governments that the VLT would help Europe become more competitive in the world, and that the project could not have been started without this support. ESO and Europe recognize that astronomy pushes on the limits of technology and that scientists and engineers will grow as they meet the challenge to build the VLT and to make it work.

ESO has hired the leader of the telescope program away from NOAO. The Director General of ESO has been quoted as crediting the European observatories' emergence as a world power in astronomy as due, in part, to America's neglect of its national observatories.

2. United Kingdom (UK)

Not a member of ESO, the UK's Science and Engineering Research Council has recently declared a UK share of at least 40% in an 8-meter telescope as one of its four key projects for groundbased atmospheric and astronomical sciences.

The UK plan closely parallels that of the NOAO. Both partners are therefore coordinating their 8-meter telescope plans and are exploring a joint project to share in the costs and benefits of building and operating such a telescope.

3. Japan

Japan has plans to build an 8-meter national telescope and has reserved a site for it on Mauna Kea, Hawaii.

The American Society of
Mechanical Engineers

Suite 218
1825 K Street, N.W.
Washington, DC 20006-1202
202-785-3756

March 31, 1989

The Honorable Doug Walgren
Chairman
Subcommittee on Science, Research and Technology
House Science, Space & Technology Committee
U.S. House of Representatives
2319 Rayburn House Office Building
Washington, D.C. 20515

Dear Chairman Walgren:

On behalf of the American Society of Mechanical Engineers Task Force on the FY 1990 National Science Foundation budget, I am pleased to enclose the Task Force's statement on this very important topic.

We request that this statement be included in the official hearing record of your recent NSF budget hearings.

If you have any questions, please contact Nancy Robleski in the Washington office.

Sincerely,

Alexander Dybbs

Alexander Dybbs, Ph.D
Chairman
Task Force on the NSF Budget

Enclosures

The American Society of
Mechanical Engineers

Suite 218
1825 K Street, N.W.
Washington, DC 20006-1202
202-785-3756

Statement of the
Task Force on the National Science Foundation
# of the
American Society of Mechanical Engineers
on the National Science Foundation
FY 1990 Budget Request

Submitted to
Subcommittee on Science, Research and Technology
Committee on Science, Space and Technology
U.S. House of Representatives
March 31, 1989

Mr. Chairman and Members of the Committee:

We appreciate the opportunity to submit our views on the proposed Fiscal Year (FY) 1990 budget request of the National Science Foundation. The American Society of Mechanical Engineers (ASME), is a non-profit educational and technical society of practicing mechanical engineers. ASME was founded over one hundred years ago, and today its membership exceeds 116,400 professionals in mechanical engineering including 19,200 students. Because of NSF's prominent role in mechanical engineering research and education, ASME has a long and continuing history of interest in both the immediate and long term direction of NSF. Our members practice many applications of engineering. Because of NSF's prominent role in mechanical engineering research and education, ASME has a long and continuing history of interest in both the immediate and long term direction of NSF.

This statement was prepared by a task force of the Council on Education of ASME and represents the consensus of that group rather than an official position of ASME.

The task force strongly endorses the Administration's plan to double the NSF budget by 1993 and we strongly urge the Congress to keep this plan on track. Our comments will focus primarily on the budget requests for the engineering programs of the Foundation. We are particularly concerned with the balance of funds between the basic and more applied areas of engineering research and the engineering education programs.

Engineering plays a key role in maintaining and strengthening the technological leadership of the United States. Engineering research provides the necessary link between scientific advances and the introduction of new processes and products. Without proper investment in this technological base, the ability of the U.S. to continue as a leader in the development of new technologies will be significantly impaired.

OVERVIEW: NSF ENGINEERING BUDGET

The FY 1990 budget request for the NSF Engineering Directorate is $211.2 million. This request is an increase of $23.9 million or 12.8 percent over the current FY 1989 plan of $187.8 million. Even if the request is approved in full, it is modest when one considers that there have not been significant increases in the NSF basic engineering programs for the last four years. If, as has recently been the case, this budget proposal will eventually be trimmed below the request, then the NSF engineering program will run the risk of having inadequate budgets. This will make it even more difficult, if not impossible, for NSF to balance its support for programs that foster economic vitality with those that ensure the long term health of basic engineering research.

In FY 1985, NSF supported a larger fraction of engineering research at universities than any other federal agency. Today, the Department of Defense is the largest source of funding for engineering research at universities. We do not wish to see engineering research at U.S. universities' become mission oriented and DOD dominated. Thus, it is important to provide significant growth in engineering research at NSF.

Almost from its inception in FY 1979, the NSF Engineering Directorate's budget has been about 10 percent of the total NSF budget. This despite growth in the NSF budget over the last few years. Given engineering's importance to the U.S., and the Engineering programs importance to engineering research and education, we believe that the Engineering Directorate budget should be larger than 10 percent of the total NSF budget. We urge Congress to provide additional funds to achieve this goal.

BALANCING PRIORITIES

The Engineering Directorate of NSF has programs in two broad areas, basic or disciplinary research and more targeted or cross disciplinary engineering research.

A summary of the budget changes both for the basic or disciplinary engineering programs and cross-disciplinary programs for the last three years are shown in the appended Table 1.

The Table 1 figures reveal that over the last three years, the basic/disciplinary programs have not kept up with inflation. These figures are typical of the funding increases for the basic/disciplinary areas over the past decade.

The proposed increases for FY 1990 in these disciplinary programs are inadequate to counter the previous lack of funding or to keep pace with inflation.

Under these circumstances, it is difficult to see how these programs can be expanded or support additional investigators. If the same budgeting constraints prevail as in the last three years, the total request will be reduced and those programs which are fortunate enough to receive even modest increases will actually experience a budget decrease after inflation.

Many external (non-NSF), and internal (NSF), R&D programs--some of which are slated for increased emphasis in FY 1990--will suffer unless they are built upon a satisfactory engineering science base. The nation's technological leadership and industrial competitiveness have historically, and will continue to rely on engineering research.

ENGINEERING EDUCATION

We endorse the proposal to increase the priority of Education and Human Resources within NSF. The intent within engineering is to "revitalize the engineering undergraduate enterprise" by doubling the funding. This is an important first step. NSF has the unique opportunity to work with educators and professional societies to conceive, advise and demonstrate innovations in engineering education. We strongly urge congressional support for this aspect of the NSF FY 1990 budget request.

CONCLUSIONS AND RECOMMENDATIONS

We support the proposed increases for the FY 1990 NSF budget for the Engineering Directorate and endorse the Foundation's commitment to developing and sustaining a high level of federal support for both engineering research and education. Given the impact that engineering can have on U.S. economic competitiveness and the importance of NSF to many areas of basic and focused engineering research, it is essential that Congress approve the proposed FY 1990 NSF budget.

Further we urge Congress to increase the NSF funding level so that the Engineering Directorate can grow to more than 10 percent of the total NSF budget. The proposed budget increases can help NSF balance its support for programs that foster economic vitality with those that ensure the long-term health of basic research.

It is our hope that the Subcommittee will view the budget as an important investment in the nation's economic and industrial future, the rewards of which the nation will reap many times over.

National Science Foundation
Engineering Directorate

TABLE 1

BASIC/DISCIPLINARY PROGRAMS *
(millions of dollars)

Activity	Actual FY1987	Actual FY1988	Current FY1989	Percent 89/87 Diff.
Chemical, BioChemical and Thermal Engr.	$28.42	$28.90	$30.5	7.3%
Mechanics, Structures and Materials Engr.	25.09	25.78	27.3	8.8%
Electrical, Comm. and Systems Engr.	22.58	23.38	24.85	10.0%
Total	$76.09	$78.06	$82.65	8.6%

CROSS DISCIPLINARY PROGRAMS *
(millions of dollars)

Activity	Actual FY1987	Actual FY1988	Current FY1989	Percent 89/87 Diff.
Design, Manuf. & Computer Integrated Engr.	$14.28	$15.38	$17.4	21.8%
Emerging Engr. Technologies	15.74	16.59	18.45	17.2%
Critical Engr. Technologies	24.68	25.11	27.55	11.6%
Cross-Disciplinary Research	32.29	36.33	41.75	22.6%
Total	$86.99	$93.41	$105.15	20.9%

* As constituted in FY 1987.

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March 2, 1989

The Honorable Doug Walgren, Chairman
Subcommittee on Science, Research and Technology
Committee on Science, Space and Technology
U. S. House of Representatives
Rayburn House Office Building, Room 2321
Washington, DC 20515

Dear Chairman Walgren:

In connection with the Subcommittee's early March hearing on the National Science Foundations's FY 1990 budget request, the Council for Chemical Research offers some facts which we believe are important and worth your consideration.

We recognize that a five-year authorization for NSF programs is in place. We are also aware, however, that the necessity of reducing the Federal budget deficit may bring new pressures to bear on the NSF request. Therefore we wish to place in your hands these facts for your use when appropriate.

The Council for Chemical Research was formed in 1979 to help strengthen the U.S. economy, competitiveness and quality of life. We do this chiefly in two ways: building more interactions between academia and industry, and improving support for basic research in chemistry and chemical engineering.

Our members represent the 157 universities where nearly all the U.S. academic research in these fields is done, and the 55 major companies which carry out most of the corresponding industrial research.

All the data we can find show that our companies contribute a much larger share of the expenditures of pertinent university departments than do any other industries to their pertinent departments.

Necessarily, however, the major source of support for this nation's scientific research in universities is the Federal Government. In the case of chemistry and chemical engineering, the combination of public and private support is uniquely well repaid, by a net positive trade balance of over $10 billion. We believe this level to be unique among technological disciplines. It is among the reasons why chemistry and chemical technology are referred to as "the central science," and why healthy support of basic research in these fields is so important to everybody.

This discipline stands out among those which offer not merely scientific prestige, but also many human benefits. It stands out in meeting the practical considerations in the National Academy's recent report to the Congress concerning priorities of science.

The spectrum of benefits to our society from chemical processes is astonishing. All food production, nearly all of our energy, most medical advances (including the promise of biotechnology), and modern materials of all types (including the promise of superconductivity) are only a few examples.

Other areas of science and engineering offer similar, though we believe less sweeping, benefits. In any event, the vital role of science and engineering leads clearly to the conclusion that the FY 1990 requests for the National Science Foundation's research and education programs and for the Department of Energy's basic energy sciences program are minimal in light of the need and should be fully allowed by the Congress. The NSF requests are $1.803 billion for research and related activities, and $190 million for science and engineering education.

There are two overriding reasons which lead to this conclusion: the central importance of new knowledge on which to base technological advances, and enlarging the pipeline of well prepared young people who can discover and use that new knowledge.

We do have one concern with the NSF budget request. Within the Engineering Directorate, the former Chemical, Biochemical and Thermal Engineering Division has been changed to "Chemical and Thermal Systems." While there is a Division of Biological and Critical Systems, bioprocess engineering does not appear there or elsewhere. To de-emphasize bioprocesses engineering, an essential area in existing and future biotechnology, would be to forego some important opportunities to maintain U.S. leadership.

It is no longer surprising to state that the United States will compete seriously in trade and will have a satisfactory quality of life only if, among other things, we maintain strong support of research, greatly improve the attracting of bright young people to preparing for careers in science, engineering and mathematics, and assure high quality of such preparation.

As to new knowledge, here, briefly, are some examples of the research opportunities in science and engineering which must be seized if the U.S. is to stay ahead or abreast of competitor nations. Some of these examples have been in the news, but others may surprise you. It takes years to achieve these things.

New materials having high ratios of strength to weight sometimes outperform steel. Others offer new capabilities in electronics, such as extraordinarily highly packed circuitry on semiconductor chips. All such new materials result from new combinations and manipulations of the chemical elements. Chemists and physicists work together to achieve the necessary new understanding.

Superconductivity, at temperatures high enough to open many attractive possibilities, depends on advanced chemical knowledge, both for understanding toward further increases in critical temperature (below which they are superconducting) and for producing them economically.

Biotechnology, often referred to as genetic engineering, is done mostly by biochemists and biochemical engineers. They study the behavior of the genetic molecules known as DNA. Their work involves discovery and use of chemical understanding to cause plants, microbes, etc. to make products which will enhance agriculture, cure disease, and even catalyze industrial processes.

Hydrogen is not only the cleanest of all fuels but one which would not contribute to the greenhouse effect. The possibility of splitting water with sunlight to form hydrogen will depend entirely on new knowledge of photochemistry and catalysis.

Combustion, a chemical process, is our energy mainstay and will be for may decades to come. As domestic oil dwindles, and when the oil cartel returns to past pricing habits, improved energy conservation will be as vital to the economy as will new energy sources. An important portion of that conservation will rely on expanded understanding of the chemistry of combustion processes, in order to raise their efficiency.

Other examples of research opportunities and frontiers are quickly presented in the attached summary reprints of reports from the National Academy Press: "Frontiers in Chemical Engineering" (1988) and "Opportunities in Chemistry" (1985).

As to the people pipeline, we read much about and are beginning to experience the worsening shortfall in numbers of bright young people who are capable of, and opting for, careers in mathematics, science and engineering.

Coming needs for well prepared people, in the laboratories which must carry out the research on which the nation's future will rely, number far beyond the count of young people who will be emerging from the pipeline when needed. A disaster threatens.

It takes at the very least a dozen years to attract and train a young scientist or engineer.

The NSF's education program encompasses a well-planned range of attacks on the problem. They prepare teachers for the task of catching the imagination of bright youngsters, starting them on roads which can lead to rewarding lifetimes in science and engineering. They reinforce this with television programs, museum exhibits and the modernizing of curricula. They enable undergraduate students, and even high school students, to get experience in real-world research. They enable college faculty to strengthen their teaching by doing cutting-edge research. They financially enable outstanding graduate students to complete advanced training. Very importantly, funds are directed to attract and enable minorities and women, and also disabled students, to move into careers in science and engineering.

NSF's research program makes a related attack on the problem. University research depends on faculty-guided efforts of graduate students and postdoctoral people. In turn, these young people are experiencing the best possible training in the many areas of science and engineering which will be crucial to the economic health and quality of life in all parts of the United States.

SUMMARY

The Council for Chemical Research draws attention to the close ties among research in science and engineering, education from early school years to postdoctoral training, the health of the U.S. economy, the U.S. quality of life, and the quality of our environment. We have n mind the long lead times involved in bringing about the benefits of science and engineering. We recognize the threats to our competitiveness, our economy, our energy systems, our environment and the global climate. Science and engineering alone cannot solve or avoid the problems, but they comprise an absolutely essential part of the solution.

With these things in mind, we urge most seriously that the Congress allow the full FY 1990 budget requests for the National Science Foundation's research ($1.803 billion) and education ($190 million) programs, and the Department of Energy's basic energy sciences program ($590 million).

We also urge reconsideration of the apparent de-emphasis on bioprocess engineering, in order to avoid a serious loss of opportunity for U.S. leadership in biotechnology.

Respectfully yours,

C. Judson King
Chairman

SOCIETY FOR AMERICAN ARCHAEOLOGY

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Statement of the Society for American Archaeology
Presented to the House Science, Space and Technology Committee
Subcommittee on Science, Research and Technology
Hearing on Fiscal 1990 Budget

March 29, 1989

Mr. Chairman, the Society for American Archaeology is pleased to have the opportunity to present this testimony for the Record in support of the fiscal 1990 budget authorization for the National Science Foundation. The SAA is requesting an increase of $1 million for the anthropology division of the NSF. The continued interest and support of your subcommittee has been a major stimulus for archaeological resource protection, research and interpretation.

The Society for American Archaeology is an international scholarly and professional association comprised of both professional and avocational archaeologists concerned about the discovery, interpretation and protection of the archaeological haritage of America. Founded in 1934, the objectives of the SAA are to promote scientific research in the archaeology of the New World by creating closer professional relations among archaeologist and other interested in American archaeology; by guiding the research work of amateurs; by advocating conservation of archaeological data and elimination of commercialization of archaeological objects; and by promoting a more rational public appreciation of the aims and limitations of archaeological research.

Contribution of Archaeology

"Archaeology" does not involve merely collecting artifacts; it is the systematic scientific study of the material remains of human life and culture. Archaeological sites contain the undocumented remains of past human activities and are fragile sources of information about the prehistory and history of the nation; prehistoric sites are the only testament of 12 millennia of cultural development of Native Americans.

Archaeology's contribution to the history of America is both unique and indispensable. It ranges from the peopling of the American continent thousands of years ago and the cultural history of Native Americans, to the first European settlements, our country's struggle for independence, the opening of the West, the transformation of rural communities and development our great cities. An accurate interpretation of the past is essential to an understanding of the history of the Untied States an our present population as a people. Much of the heritage of this country is represented solely by the tangible undocumented remains of our past, and this is what archaeology recovers, interprets and preserves.

Archaeology Faces National Crisis

Archaeological site looting is increasing at an alarming and rapid rate. Federal agencies, Congressional committees and professional organizations reports, including but not limited to, Cultural Resources: Problems Protecting and Preserving Federal Archaeological Resources by the General Accounting Office; The Theft of Indian Artifacts from Archaeological Sites, Oversight Hearing by the Subcommittee on General Oversight and Investigation, House Interior Committee; Management of Archaeological and Paleontological Resources on Federal Lands, Hearing of Subcommittee on Public Lands, Reserved Water and Resources Conservation, Senate Committee on Energy and Resources; and Looting America's Archeological Heritage by the National Park Service, document an alarming and rapid increase in the looting of sites on public, private and Indian lands.

Statistics from these reports cite dramatic examples of a national crisis. For example, nearly 90% of known sites on federal lands in the Four Corners area of the southwest (New Mexico, Arizona, Utah and Colorado) have been looted or vandalized. The Fish and Wildlife Service estimates that one-third of the 800 known Indian archaeological sites on refuge lands in the area have been damaged; most of this disturbance occurred in the last 10 to 15 years. The Forest Service estimates that nearly 100% of the Classic Mimbres sites in southwestern New Mexico have been vandalized. According to National Park Service statistics, the number of reported incidents of looting and vandalism of sites on federal lands increased 42% from fiscal 1985 to fiscal 1986. The National Oceanic and Atmospheric Administration has experienced looting of underwater sites from Key Largo in Florida to the Channel Islands in California.

On Indian lands, a 1000% increase of site looting and vandalism occurred between 1980 and 1987. Some experts, including federal land managers and law enforcement personnel, believe this resulted from looters shifting their activities onto Indian lands because of increased enforcement on federal lands. Very little is known statistically about the extent of looting on private lands or on state or local public lands. Evidence from the sources cited above show that looting or archaeological sites on private land is rampant throughout the country.

Our scientific database is being systematically destroyed for personal gain. The NSF can play a key role in the future of archaeology. With the documented loss of archaeological resources reaching crisis proportion from looting and vandalism, it is more crucial than ever that sufficient funds be available for basic archaeological research. Archaeologists are not like other scientists who can seek significant funding at the National Institutes of Health, the Department of Defense and other federal agencies. NSF is the only major source of funding for basic scientific archaeological research.

Archaeology at the National Science Foundation

Archaeology at the National Science Foundation is funded through the anthropology program in the Behavioral and Neural Sciences Division. Although the NSF has played a critical role in the development of scientific archaeology and has been highly cooperative with the archaeological profession, it has relatively limited funds which are getting tighter than ever before.

The Administration FY 1990 budget has budgeted $2.2 billion for the National Science Foundation's overall budget. Of this the Behavioral and Neural Sciences Division's increase are The Anthropology Program is slated for a 3.5% increase from $7.73 million in FY 89 to $8.0 million in fiscal 1990. This is only an increase of $270,000 of which archaeological research receives only a part. The program also supports other subdisciplines of anthropology. The other programs within the Division received fairly substantial increases.

Summary of Fiscal 1990 Programs in Behavioral and Neural Sciences Division

	FY 89	FY 90	$ change	%
Anthropology	7.73	8.00	.270	3.5
Language Cognition	9.50	10.20	.700	7.4
Biology of Behavior	11.62	12.95	1.133	11.4
Neuroscience	15.96	17.13	1.170	7.3

The Society for American Archaeology is requesting an increase of $1 million to be specifically earmarked for the anthropology program. Accompanying report language indicating the intent of the Committee that these funds be used for archaeological research would be very useful.

The Society thanks the Committee for the opportunity to present this statement.

Appendix IV

NATIONAL SCIENCE FOUNDATION
WASHINGTON D C 20550

nsf

OFFICE OF THE
DIRECTOR

January 5, 1989

RECEIVED
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Committee on [illegible]
and Technology

The Honorable Robert Roe
Chairman
Science, Space, and Technology Committee
2321 Rayburn House Office Building
House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

I am transmitting the Foundation report on the status of science education in two-year and community colleges. The report is in response to H.R. 2330, the House-passed NSF authorization legislation requesting the Director of the Foundation to submit "to the House Committee on Science, Space, and Technology and the Senate Committee on Labor and Human Resources, a report on the state of science, technology, and engineering programs in the nation's two-year and community colleges."

The report provides a descriptive profile of two-year college science, mathematics, technology, and engineering faculty, students, curriculum, and laboratory programs. Specific areas of need are described for each of these important components.

Finally, the report describes the current and potential role of the Foundation in responding to the needs of two-year colleges. These activities and recommendations are consistent with the Foundation's undergraduate science, engineering, and mathematics education budget requests and strategic plan required under the Education for Economic Security Act (P.L. 99-159).

I look forward to having further discussions with you regarding these institutions.

Sincerely,

Erich Bloch
Director

Enclosures

cc: The Honorable Robert Walker

SCIENCE AND ENGINEERING EDUCATION

IN

TWO-YEAR COLLEGES

Prepared by

The National Science Foundation

January 1989

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EXECUTIVE SUMMARY

Within two-year college enrollments, valuable human resources are available if nurtured and provided with stimulating learning opportunities in science, mathematics, and engineering. These students have an interest in continuing their education in four-year institutions. However, the current science and engineering courses and programs capture too few of them.

Problems in science and engineering for two-year and community colleges are consistent with those of four-year institutions: keeping faculty up-to-date in their fields, developing courses and programs of study that will attract and retain students - particularly minorities and women, developing the laboratory component of science and engineering courses, and making sure that there is a strong articulation with the precollege experience of science, mathematics, and engineering students.

The most salient attributes of two-year colleges are - a) access to higher education for those who might not otherwise have such opportunities, b) diversity of learning purpose ranging from personal growth courses and remediation to the first two years of college; and c) significant enrollments of minority and low-income students. These institutions represent the last chance for many students to continue their formal education. They provide courses which will prepare students for college work and they offer the first two years of college science, mathematics, and engineering.

Over 1300 two-year colleges in the United States --70 percent public and 30 percent private-- enroll 4.7 million students. This represents half of the minorities in higher education and 37 percent of all college students. While these institutions serve a variety of purposes for students, they have a single dominant mission -- instruction.

Given the changing demographics of the population and the needs of the future work force, these institutions have the potential to meet important pipeline needs for the fields of science and technology. In particular, they offer an important opportunity to attract significant numbers of minorities into science and engineering.

Among the many functions that two-year colleges serve, two are particularly important for the fields of science and engineering. They provide the courses and programs needed during the first two years of college-level science and engineering. And, they offer prerequisite courses that provide students with the knowledge needed to begin college studies in these fields.

Problems

Two-year colleges have important but not insurmountable problems in their science, mathematics, and engineering programs.

Faculty

Faculty members are not as well prepared as they need to be to keep their courses and instructional programs timely and engaging. Limited professional development opportunities, heavy teaching loads, and the lack of a scholarly tradition keep many two-year college faculty in isolation from the mainstream of their science, mathematics, or engineering disciplines. Since teaching is the mission of two-year colleges, research is not a faculty responsibility; however, faculty often lack the time and collegial interaction to develop other scholarly pursuits which keep them in tune with events and discoveries in their scientific or engineering fields of teaching. This problem is more acute today with about half of the faculty in the last third of their careers and distant from academic preparation in science and engineering.

Students

Students in two-year institutions share common problems with all higher education students vis-a-vis science and engineering -- a lack of preparation for college level science and mathematics, lack of motivation to pursue science and engineering, and a decrease in interest the longer they stay in college. Two-year colleges attract a large number of minority and low-income students, many of whom express an interest in science or engineering. However, minority students are less likely than their majority peers to actually transfer to a four-year institution, and even less likely to complete a baccalaureate in science or engineering.

Curriculum, Course Content, Laboratories, and Instructional Equipment

The basic challenge for two-year colleges is to increase the quality of learning for students in science, mathematics, and engineering. This must be done in a way that engages and retains students. Students who are not prepared for college work need challenging, stimulating courses which provide prerequisites and motivate them to continue such study.

The laboratory and equipment needs are in two important areas. Two-year colleges need to upgrade their instructional laboratories and improve the availability of modern instructional equipment.

The Federal Role

The Federal government plays an important role in the two-year college arena. For example, the Department of Education is largely responsible for student assistance and plays a role in the improvement of adult and vocational education. The Department of Labor plays a role in job training and basic adult literacy areas.

The National Science Foundation - A Targeted Role

The appropriate role for the National Science Foundation is one of intellectual and substantive leadership. The Foundation is able to draw upon its position in the science and engineering communities to provide leadership, developmental support, and intellectual resources to strengthen two-year college science and engineering.

The Foundation's leadership will be most effective in making sure that the quality of funded programs are consistent with sound scientific and engineering principles. The Foundation is in a particularly strong position to leverage its resources through its undergraduate programs and planned innovative initiatives which increase the collaboration among two and four-year colleges.

The Foundation is best able to focus on three areas which affect all parts of the instructional programs in science and engineering -- faculty, curriculum, and laboratories. Programmatically, the Foundation includes two-year colleges as eligible participants in four areas: 1) faculty enhancement in the content areas of science, mathematics, and engineering, 2) curriculum and instructional improvement, 3) the development of laboratory components of science and engineering programs, and 4) collaborations - a) to improve articulation between two-year college and secondary school science and mathematics programs, and b) to improve cooperation and articulation between two-and four- year institutions of higher education.

If two-year college students are to improve their chances for future learning and success in an increasingly technological economy, they must persist in their science, mathematics, and/or engineering studies. Large numbers of these students do not. Programs in science, mathematics, and engineering must be developed to make them more attractive and engaging for two-year college students.

SCIENCE, TECHNOLOGY, AND ENGINEERING EDUCATION IN TWO-YEAR AND COMMUNITY COLLEGES

Background

This report is prepared for the United States Congress in response to the request of the United States House of Representatives, HR-2330 (passed by the House of Representatives, 100th Congress, 1987). The Congress asked the Foundation to assess the status of science and engineering programs, describe their most significant deficiencies, and provide recommended actions that the Foundation take to address problems and deficiencies.

The report is based on the background materials and report of the National Science Board Task Committee on Undergraduate Science and Engineering Education, Undergraduate Science, Mathematics and Engineering Education. (NSB, Washington, D.C., March 1986) and four reports commissioned by the Foundation in 1988. A set of three reports was prepared by Westat, Inc. of Rockville, MD:

> "The Curriculum: A Coding of Two-Year and Community College Catalog Information" (Cahalan, et al, 1988a);
>
> "Pretest Survey of Two-Year and Community Colleges on Science and Technology Education" (Cahalan, et al, 1988b) - n.b. The 20 institutions in the pretest are not a national sample; however, their responses represent a preliminary picture of current problems and issues facing community colleges);
>
> "A Review of Selected Data on Two-Year and Community College Science, Mathematics, and Technology Programs" (Cunniff, 1988).

A summary of research and analyses was prepared by the Center for the Study of Community Colleges, Los Angeles, CA:

> "A Preliminary Review of Natural Science, Mathematics, and Engineering Education in Community Colleges in 1988," (Cohen and Brawer, 1988).

Introduction

Two-year colleges have several unique characteristics among institutions of higher education. Because of their diversity in educational programs and student populations, they provide access to higher education for millions of students. Their locations in urban and rural areas make them attractive for low-income and minority students who, if not for these institutions, would be left out of higher education. For students who did not take sufficient science or mathematics courses in their pre-college years, two-year colleges offer a last chance to recapture a lost opportunity to pursue a formal higher education.

Two-year colleges offer a beginning postsecondary education step for many potential scientists and engineers. They offer the beginning two years of college level courses in scientific and engineering fields. Over half of the students in these courses intend to earn the baccalaureate degree. In addition, these institutions play an important role in efforts to increase minorities and women among the ranks of scientists and engineers because of the large number of minority students enrolled.

Of the total science and engineering Ph.D.s in 1987, 10% attended community colleges. Among minority Ph.D.'s, this percentage was 10 percent for blacks, 13 percent for Hispanics, and 25 percent for Native Americans (Cohen and Brawer, 1988).

A DESCRIPTIVE PROFILE OF TWO-YEAR COLLEGE STUDENTS, FACULTY, CURRICULUM, AND INSTRUCTIONAL LABORATORIES[1]

There are 1336 two year colleges in the United States. While 70 percent are public and 30 percent are private, 94 percent of two-year college students attend public institutions. These two-year colleges offer postsecondary education to students who attend for one or more of the following five major purposes (Cunniff, 1988; Cohen and Brawer, 1988) because they offer:

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[1] The data cited in this report are provided by the National Center for Education Statistics (NCES 1988) unless cited otherwise.

- the first two-years of a baccalaureate program for students who intend to transfer to four-year colleges or universities.
- a chance for the high school graduate to pick up science and mathematics courses which serve as prerequisites for college level work.
- opportunities to pursue career or occupational programs for entry level knowledge and skills.
- continuing or adult education for personal interest, professional development or occupational upgrading.
- economic development activities, such as retraining adult or displaced workers and custom training for new or changing business and industry.

In addition to formal education, these institutions often provide community service and personal interest experiences, such as seminars, recreational and cultural learning, and other short term experiences.

FACULTY

Two-year colleges in the United States employ 215,000 faculty members. These faculty represent a significant portion of the higher education community but, when surveyed, perceive themselves as out of touch with the mainstream of their teaching disciplines (Luskin, 1987). Faculty are interested in doing a better job, but are concerned about the lack of professional development opportunities available to them (Cohen and Brawer, 1988). Listed below are several important, common characteristics of two-year and community college teachers.

- Two-year college faculty spend the overwhelming majority of their time in instructional activities and have heavier teaching loads than faculty in four-year institutions. The instructional workload contributes to the perception among science faculty that they are isolated from contact with the mainstream of their academic fields. And, they have limited time or opportunities to develop and improve themselves, their courses, and the curricula.

- About one-fourth of the science and engineering faculty have the doctorate; however, the degree is often not in science or engineering.

- Sixty percent of two-year college science and engineering faculty are employed on a full-time basis. This is compared to the 40 percent of all two-year college faculty who are full time. In contrast, about 80 percent of four-year college and university faculty are employed full time.

- Three-fourths of all community college faculties are white males. Eighteen percent of the faculty are women and 6 percent are minorities. About half of the community college faculty are in the last third of their careers (NSB, 1986).

- Science, mathematics, and engineering are among the most difficult areas of faculty recruitment in two-year colleges. Two-year college faculty make about $4,000 or 12 percent less than the average yearly salary of four-year college faculty.

Areas of Faculty Need

The most salient two-year college faculty problems include the following.

- Faculty Preparation. Two-year college faculty need better preparation in and up-to-date knowledge of science and engineering disciplines. In addition, part-time two-year college faculty are less well prepared than their full time counterparts. Two-year colleges need to be more selective in or provide training opportunities for the part-time faculty they hire.

- Faculty Teaching Enhancement. Opportunities to gain current knowledge and participate in professional activities related to their teaching disciplines are not included as part of the current community college faculty work structure.

- Professional Development. Professional development among these two-year college faculty is particularly important for those who have not been actively engaged in disciplinary work.

- Faculty Turnover. The lack of turnover among two-year college faculty in science and engineering is due to the current aging teacher cohort and limited student interest in these areas (Cohen and Brawer, 1988). Therefore, these colleges have not hired significant numbers of new faculty recently prepared in science, mathematics, and engineering disciplines.

- Faculty Demographics. Women and minorities make up small percentages of the faculty that teach natural science and engineering in two-year and community colleges. Two-year colleges will need to develop specific strategies to attract and retain women and minority science, mathematics, and engineering faculty.

STUDENTS

Half of all students who pursue postsecondary education begin their college work in two-year colleges. These colleges enroll about 4.7 million students. This is 37 percent of all college students and 47 percent of all ethnic minorities in higher education -- 43.1 percent of all black college students, 55.3 percent of all Hispanics, and 43 percent of all Asians.

The diverse purposes for which students pursue postsecondary education in two-year colleges (see p. 2) accounts, in part, for the fact that about two-thirds of the students are part-timers. This is compared to the one-third part-time undergraduate student population in all institutions of higher education.

About half of all students entering community colleges have aspirations which require the attainment of a baccalaureate; however, there are no reliable national data on the proportion of community college students who go on to four-year institutions.

Several state or regional studies indicate that fewer minority students complete the associate degree program than their majority counterparts (Cunniff, 1988).

STUDENTS IN NATURAL SCIENCE, MATHEMATICS, AND ENGINEERING

Students enrolled in two-year college science, mathematics, and engineering programs differ from the general two-year student population. More of the science students enjoy full-time status and more intend to go on to four-year institutions. They have higher academic aspirations than the overall two-year college student population. They represent a rich potential human resource for the fields of science, technology, and engineering.

Students enrolling in natural science are more likely than their peers in "science-related" fields to be preparing for a transfer to a four-year institution of higher education. Fifty-three percent of those taking biological and physical sciences, and 52 percent of those in mathematical sciences plan to transfer to four-year colleges or universities.

Students specializing in science related fields such as health, computer, and engineering are more likely to be preparing for a new job or upgrading their job skills. Only, twenty percent in health (e.g., nursing, paramedical preparation, and so on), 30 percent in computer science, and 24 percent in engineering plan to transfer to four-year institutions.

Two-year college science and engineering programs, consistent with a pattern in all of higher education, have difficulty retaining student interest and participation. This a particulary acute problem among minority students. That is, many two-year college students who start in science and engineering programs do not continue past two years. And, among those that go on to four-year colleges, many decide not to earn their undergraduate degrees in science, mathematics, or engineering (Cohen and Brawer, 1988; Cunniff, 1988 -- see below).

- Overall, only about 20 percent of all community college students who enroll a science, mathematics, or engineering course plan to pursue the baccalaureate in these fields.

- There is some drop in interest within the two-year college experience. Among the 30 percent of 1985 community college freshmen indicating an interest in science, engineering, or science related fields (including engineering technology and health professions), about 86 percent retained that interest two years later.

Ethnic and gender balance.

- Access to higher education for minority students is a major attribute of community colleges. Minorities --Black, Hispanic, Asian, and Native American students-- comprise about 22 percent of all two-year college students compared to the 15 percent minority enrollment in four-year institutions. Minorities earn 12 percent of all baccalaureate degrees; however, minorities receive 16 percent of all associate (two-year) degrees.

- Minorities make up 25% of the science classes (slightly higher than their overall representation in two-year institutions); they enjoy a slightly higher representation in mathematics and allied health courses, but are underrepresented (vis-a-vis their proportion of student enrollment in two-year colleges) in computer science and engineering.

- Engineering is overwhelmingly dominated by male students (91%) in community colleges. Males are also overrepresented in physical science, computer science, mathematics, and engineering technologies. However, men are underrepresented in the life and social sciences.

Areas of Need Related to Students in Two-Year Colleges

Student problems in two-year college science and engineering are similar to those in four-year institutions of higher education. They lack preparation for college work in science and mathematics prior to entry. They indicate limited interest in pursuing science and engineering fields of study. And, they exhibit weak persistance in these fields when they do enter.

- Students need challenging, stimulating courses which provide prerequisites _and_ motivate continued such study in science and related fields because they represent a significant population in the pipeline of potential scientists and engineers.

- The low level of two-year college student interest in natural science seems to diminish even further the longer those students remain in college.

- As in all institutions of higher education, two-year colleges have a difficult time recruiting and maintaining minority students in science and engineering programs.

Community colleges need to increase the quality of the learning experience for students in science, mathematics, and engineering courses. And, it should be done in a way that engages and retains students. There is a particularly compelling opportunity to provide such an academic program for minority students.

CURRICULUM / COURSES

The nation's two-year colleges face a formidable challenge in the science, mathematics, and engineering curriculum areas. The diversity of student need and interest require that they provide college-level, vocational/technical, and remedial courses.

These colleges offer a wide variety of courses including:

- the first two years of college courses appropriate for students who wish to transfer to four-year institutions;

- a "last chance" curriculum for the large number of high school graduates who missed (or never had) the opportunity to take the secondary school courses required as prerequisites for college work;

- a series of no-credit remedial courses, especially in mathematics;

- a large variety of technical courses related to medical, computer, and technology fields; and

- courses preparatory for careers in what is called the "allied health professions" -- nursing, radiology, and paramedical services.

While two-year college course-taking in science and engineering declined from the mid-1970's to the mid-1980's, the number of mathematics and computer science courses increased in that period. In 1978 mathematics and computer science accounted for 22 percent of all science related classes; in 1986 that proportion rose to 41 percent.

The following national picture is derived from a study of course offerings in public and private two-year colleges (Cahalan, 1988a). The two-year colleges not offering science and technology courses are nearly all private.

- The percentage of two-year colleges offering science and technology courses ranges from 66 percent for earth sciences to 92 percent for mathematics. Over 80 percent of all two-year institutions offer courses in biology, chemistry, physics, and engineering.

- Biology, computer science, and mathematics are offered by nearly all (99%) public two-year colleges. The overwhelming majority of these institutions offer engineering/engineering technology courses (98%), chemistry (95%), physics (94%), and allied health (92%). Fewer of these colleges offer earth and space science (79%) and agriculture/natural resources (61%).

- Eighty-nine percent of public two-year colleges (50 % of private) offer college level calculus (78% of all two-year colleges).

- The mean number of science courses offered is 8 each for chemistry, physics, and earth science; 13 for biology, and 17 each for mathematics and computer science.

Science and mathematics course offerings in two-year colleges include those typical of the first two years of college level science. Examples of college level science and mathematics courses are listed below.

- Courses offered in biology include General Biology, Human Anatomy and Physiology, Human Genetics, Zoology, Botany, and Microbiology.

- In chemistry, courses offered include General Chemistry, Quantitative Analyses, Organic Chemistry, and Chemical Thermodynamics.

- Physics offerings include General Physics, Atomic and Nuclear Physics.

- The mathematics offerings in two-year colleges include courses such as: College Algebra, Statistics, Probability, Finite Mathematics, Calculus I, II, and III, and Linear Algebra.

Areas of Need Related to Curriculum

Given the two-year college student population and the need to increase student interest in science and engineering education, the most pressing problem in the curricular area is to develop an appropriate balance of effective course offerings. These course offerings should include--

- a set of college level science, mathematics and engineering courses that articulate (facilitate the transfer of credits) well with the advanced courses offered at the nation's four-year colleges.

- science, mathematics, and engineering programs that will attract and retain students, particularly minorities and women.

- remedial courses, especially in mathematics, that address deficiencies and bring the students to the point needed to earn college-level credit in science and mathematics.

- courses of study which will allow students to gain fundamental scientific and technical literacy, whether they become employed in science and engineering or not.

LABORATORY INSTRUCTION

Although two-year college faculty have available and use a variety of instructional technologies such as television, transparencies, and models, instructors still rely on the chalk board as their primary teaching instrument (Cohen and Brawer, 1988). To properly teach science and engineering courses, laboratory facilities and modern equipment are essential.

Efforts to improve laboratory instruction raise two important concerns: the quality of facilities and equipment and the effectiveness of instructional methods and programs using such equipment. Capital expenditures in facilities and equipment are largely the responsibility of state and local taxing jurisdictions. Recently, cooperative ventures with business and industry have been launched with community and technical two-year institutions to gain access to modern equipment for instruction. Many of these cooperative ventures are in the areas of engineering technology.

Just as important, is the need to develop instructional programs using up-to-date equipment and facilities. It is of little use to acquire new equipment without creative and innovative ways to engage student interest in the learning process. Properly developed, laboratory instruction can be the basis of student motivation to continue their science studies. Poorly developed laboratory instruction can have just the opposite effect.

- In recent interviews with 20 two-year colleges, over one in four of the responding institutions believe that their laboratory facilities and equipment used for instruction are inadequate. Engineering and engineering technology facilities were judged deficient by over a third of the responding two-year campuses (Cahalan 1988b).

- When it comes to funds for the purchase of modern equipment for science laboratories, over half of the responding institutions find this to be a serious problem; over 60 percent of the institutions believe that this is a serious problem in engineering.

- One in four of the responding institutions indicate that adequate computer facilities are a serious problem in mathematics instruction.

Areas of Need Related to Laboratory Instruction

The issues related to laboratory equipment and facilities reach beyond simple availability. Two-year colleges must adequately develop the instructional laboratory component of science, engineering, and mathematics programs. The greatest problems in this area are common to all of higher education, the need to renovate facilities or purchase large scale equipment.

No single source is able to update and renovate all the equipment and facilities in two-year colleges. Some of these institutions have developed partnerships with business and industry. Others have entered into consortia with other institutions of higher education. And, state and local revenues have been used to develop the equipment and facilities of these institutions, as part of state or local economic development programs.

A major problem, often neglected, is the development of the laboratory instructional program. Some areas of science, mathematics, and engineering have important but modest equipment needs; however, they lack the developmental resources to assure high quality instructional programs that make use of the available equipment and facilities.

THE ROLE OF THE NATIONAL SCIENCE FOUNDATION

> "The National Science Foundation should take bold steps to establish itself in a position of leadership to advance and maintain the quality of education in engineering, mathematics, and the sciences." (National Science Board, 1986)

With these words, the report of the National Science Board Task Committee on Undergraduate Science and Engineering Education, (the "Neal Report") made it clear that the Foundation must play a leadership role in all phases and levels of undergraduate education. The Neal report calls for particular emphasis on underrepresented groups, such as minorities, women, and the physically disabled. And, the NSB report called specific attention to concerns of two-year institutions:

> "The two-year colleges are part of higher education. Their transfer programs provide large numbers of upper division students to four-year institutions. Articulation of this transfer point is difficult and requires serious and permanent collaborative efforts between the source and acceptor colleges." (NSB, 1986 p. 34).

The National Science Foundation is in a unique position to draw together scientific, engineering, and education communities to help strengthen two-year college science, mathematics, and engineering education. The Foundation is also in a position, through its programs, to stimulate innovative initiatives and collaboration among two-year and four-year institutions.

The Neal Report outlines five "current areas of highest priority" for the Foundation vis-a-vis all of undergraduate education. And, they recommend a specific two-year college strategy which entails collaboration among two and four-year institutions. Such collaborations would assure high quality programs and nurture efforts to increase the numbers of two-year college students who transfer to and complete four-year college science and engineering programs. The general strategies include:

- laboratory development and instrumentation
- faculty professional development
- course and curriculum improvement
- comprehensive improvement projects (which include several of these priorities and/or consortia efforts among institutions)
- undergraduate research participation

In preparation for this report, the Foundation staff consulted with other federal agencies which play a role in the educational improvement of two-year colleges and their students. For example, the Department of Education's principal role is in the area of student assistance and in adult and vocational education areas. The Department of Labor is playing an active role in funding state and local programs for job training, the retraining of displaced adult workers, and basic adult literacy programs.

The Foundation plays a more targeted role. First, the Foundation provides leadership ensuring that the quality of any funded program is consistent with sound scientific and engineering principles. This applies equally to any two-year college awards. And, the Foundation provides developmental support -- consistent with the NSF Undergraduate Science, Engineering, and Mathematics Education (USEME) programs and policies -- focused on faculty, curriculum, and laboratories, areas with the greatest potential for change in two-year college instruction.

NSF LEADERSHIP

This analysis, the current programs and strategic five-year plan of NSF USEME, and the NSB report on undergraduate education make it clear that the most appropriate programmatic efforts should be in the areas of faculty enhancement, course and curriculum improvement, laboratory instruction, and consortia among two and four-year colleges. Two-year colleges are eligible for all of the existing programs (faculty, laboratory, and curricular). And, the NSF Science and Engineering Education Strategic Plan calls for USEME to initiate a program which develops consortia among two and four-year institutions of higher education. Brief descriptions follow:

Faculty Enhancement. Faculty development efforts are directed both at the professional growth of faculty in their science and engineering teaching disciplines and the professional development of faculty so they are able to improve courses and strengthen programs, making them more attractive and engaging to students.

Course and Curricula Improvement. Courses must not only reflect the essential content of the discipline, they must also be engaging and creative, providing opportunities for active learning in laboratories and other aspects of instruction. Course and curricula development initiatives address the transition between secondary and postsecondary education and the articulation for students who transfer from two-year to four-year colleges.

Instructional Laboratory Improvement. Support for improving the laboratory component of science and engineering programs includes upgrading instructional equipment. Just as important, is the need to develop engaging learning experiences that exploit the laboratory opportunity.

Consortia among Two and Four-year Colleges and Universities. Many of the priorities outlined in this report require a comprehensive, simultaneous approach of faculty, institution, curriculum, and laboratory improvement. Programs should be consistent with the courses of study in four-year institutions. Further, successful programs will begin with the recruitment, nurturing, and support for secondary students.

NSF - USEME Five-Year Plan for Institutional Development. Collaborations are to be part of a specific USEME program initiative in the area of institutional development:

> The SEE/USEME plans to initiate a program of institutional challenge grants to colleges, universities, and consortia to support correlated and integrated sets of projects designed to improve undergraduate

> instructional programs (with emphasis on cost-sharing, and on encouragement of partnerships with private sector organizations).
>
> A major subprogram will provide incentives for forming consortia each involving a lead university (or 4-year college) and a group of 2-year colleges to work on articulation between these types of institutions and to develop coordinated projects for improving lower division instruction in mathematics, the sciences, and pre-engineering technology. (*The NSF Science and Engineering Education Strategic Plan* FY1988-FY1992, December 1987, p. 20)

The synergistic effect of collaborative programs is possible under the current programs of the Foundation. Two-year colleges are eligible to submit proposals in USEME and all NSF programs and collaborative efforts are encouraged in undergraduate program announcements.

As the strategic plan of the Foundation suggests, USEME, within the context of its existing programs, may support two and four-year college/university collaborations for faculty enhancement, course or curricula development, and improved articulation between two and four-year colleges - and between secondary schools and two-year institutions. These would be funded on a merit, competitive basis to consortia consisting of a central university or four-year college together with a network of area two-year colleges.

As a consequence, the Foundation seeks to realize two major outcomes of two and four-year college collaborations. First they would play a major role in the expanded contribution of two-year colleges in meeting the national human capital needs demanded by an economy increasingly dominated by science and technology. And, they would also engage in activities designed to significantly increase participation and persistance in science and engineering by the large number of minority students who start their college education in two-year institutions.

Activities would focus on clearly laid plans to strengthen and update the two-year college faculty and their courses. Emphasis will be on producing two-year college graduates with high quality preparation in their lower division science and mathematics courses, who can continue at the upper division institutions successfully and with minimum difficulty.

Faculty development. Two and four-year consortia are in a position to establish a variety of faculty enhancement programs, such as faculty networks to share scientific and engineering knowledge, joint scholarship and exploration, summer institutes and year-long forums for faculty in their teaching disciplines, and experiences with laboratory programs for students.

Course improvement. Consortia can make sure that two-year college faculty have an understanding of the course demands of four-year institutions and will be in a strong position to develop course and curricula in science and engineering that will reflect the latest thinking in undergraduate scientific and engineering content development (with direct ties to science societies, the Foundation, and the Academies).

Student motivation, particularly for minorities. Consortia efforts can assist two-year colleges to develop aggressive outreach programs to make sure that minority students who start programs in science and engineering do not leave because of neglect or disinterest. Closely coupled with program and course development efforts, these collaborations will be in a position to bring a wide variety of human and material resources otherwise not available to two-year college faculty and administrators.

Successful student transfer from two to four-year colleges - and - the transition between secondary school and college. Consortia can help secondary schools, two-year colleges, and four-year institutions of higher education develop programs which meet the articulation needs for students, particularly minorities, with interest in science, mathematics, and engineering. For example, the "2+2+2" programs developed in some states nurture, guide, and provide engaging learning experiences in the last two secondary school years, the two-year college experiences, and the transition to and successful completion of the four-year science or engineering program.

NSF and Two-Year Colleges - A Current Dialogue. In addition to these programmatic opportunities, the Foundation's Directorate for Science and Engineering Education (SEE) has established a dialogue with two-year college presidents, faculty, and national associations. A workshop, sponsored by SEE-USEME, was held in Washington, D.C. on October 31-November 1, 1988. Nearly two-dozen workshop participants, representing a geographic and institutional diversity in two-year colleges, shared issues and problems related to two-year college science, mathematics, and engineering programs. The Foundation's current activities and role were discussed; future activities and roles were explored. The workshop is expected to present a summary report to the Foundation and two-year college community as one outcome of the meeting.

Participants discussed efforts to overcome the isolation of two-year college faculty from their science and engineering colleagues in business, industry, and universities. In a recent article, George B. Vaughn, president of Piedmont Virginia Community College, calls upon community colleges to actively reward a wide array of scholarly pursuits. He argues that research is not the mission or goal of community colleges; however, broadly-defined scholarship clearly must be included in the two-year college professional portfolio. Such scholarship in the form of writing reviews of literature specific to scientific or engineering disciplines, lectures and forums, reviews of research, and other forms of inquiry and expression requires a solid foundation in the teaching discipline (Vaughn 1988).

The point is important for the Foundation's efforts to improve learning opportunities and experiences for students. Programs for faculty, course development, and laboratory improvement in two-year colleges will only be sustained when faculty members are actively engaged in all phases of improvement. And, faculty should have access to the most timely and important knowledge in order to make the appropriate choices in program design, development, and implementation.

CONCLUSION

Two-year colleges are devoted to instructional activities. They offer the best chance for continuing formal education for those who are ill-prepared or who cannot afford to attend four-year colleges. A unique attribute is that they provide access to these students and, at the same time, offer courses which will enable students to pursue further education and careers in science, mathematics, and engineering.

If two-year college students are to improve their chances for future learning and success in an increasingly technological economy, they must persist in their science, mathematics, and/or engineering studies. Large numbers of these students do not. Programs in science, mathematics, and engineering must be developed that are more attractive and engaging for two-year college students.

This report provides a current understanding of the status of science, mathematics, and engineering education in two-year colleges. There have been four primary areas of focus: faculty, students, courses/curriculum, and equipment/ facilities. In each case an overview has been followed by a brief summary of the most pressing problems or areas of deficiency.

The most appropriate role for the Foundation lies within its leadership and programmatic capacities. It is designed to provide maximum leverage of resources to improve the education of community college students in general and for those who go on to four-year institutions in particular.

SOURCES

Cahalan, Margaret, et al, Course Offerings in Science and Technology by Two-Year and Community Colleges, 1988, report to the National Science Foundation (Westat, Inc., Rockville, MD, September, 1988).

Cahalan, Margaret, et al, Pretest Survey Report on Science and Technology Education in Two-Year and Community Colleges, report to the National Science Foundation (Westat, Inc., Rockville, MD, September, 1988).

Cohen, Arthur M., and Florence B. Brawer, A Preliminary Review of Natural Science, Mathematics, and Engineering Education in Community Colleges in 1988, report to the National Science Foundation (Center for the Study of Community Colleges, Los Angeles, CA, September 1988).

Cunniff, Patricia, et al, A Review of Selected Data on Two-Year and Community College Science, Mathematics and Technology Programs, report to the National Science Foundation (Westat, Inc., Rockville, MD, September, 1988).

Luskin, Bernard J. "The Role of the National Science Foundation in Undergraduate Science and Engineering Education." in Undergraduate Science, Mathematics and Engineering Education, Volume II, Source Materials (National Science Board, November 1987).

National Center for Education Statistics, Digest of Education Statistics 1988 (U.S. Department of Education, Office of Educational Research and Improvement, Washington, D.C., 1988).

National Science Board, Undergraduate Science, Mathematics and Engineering Education, Report of the NSB Task Committee on Undergraduate Science and Engineering Education (NSB, Washington, DC, March 1986).

National Science Foundation, Science and Engineering Indicators - 1987 (National Science Board, Washington, D.C., 1987).

National Science Foundation, "Enhancing the Quality of Science, Mathematics, and Engineering Education in the united States: Strategic Plan for FY1988 - FY1992 (NSF, Washington, DC, December 7, 1987).

Vaughn, George B., "Scholarship in Community Colleges - The Path to Respect," Educational Record, Spring 1988.

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

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OFFICE OF THE
DIRECTOR

January 5, 1989

The Honorable Doug Walgren
Chairman
Subcommittee on Science, Research
and Technology
Committee on Science, Space and Technology
U.S. House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

Enclosed is the Foundation report on science and mathematics teacher recruitment and retention -- "salary and other factors affecting the quality of the teaching workforce." The report is in response to H.R. 2330 requesting the Director of the Foundation "to submit to the House Committee on Science, Space, and Technology and the Senate Committee on Labor and Human Resources, a report on the impact of salary levels on the recruitment and retention of science and mathematics teachers at pre-college levels."

The report provides a description of the critical factors affecting the recruitment and retention of science and mathematics teachers -- salaries, professional conditions of schools and teaching careers, occupational status of teachers, and professional development opportunities. The report also describes policy alternatives and activities proposed or in place at the state and local levels, including -- as requested in the legislation -- brief case studies of several school systems using salaries as incentives for recruitment and retention. Policy areas include financial assistance for prospective teachers, alternative certification programs, salary and other financial incentives for retention, and recruitment and retention strategies focused on professional conditions of schools and teaching.

The report includes policy options and programmatic incentives at the state and local levels with a particular focus on urban science and mathematics education. Finally, the report concludes with a description of programs and activities which the Foundation is doing or plans to do with regard to improvements in teaching, the conditions of teaching, and the careers of teachers to increase the recruitment and retention of high quality science and mathematics teachers.

I look forward to discussing these important issues with you and members of the Committee.

Sincerely,

Erich Bloch
Director

Enclosures

cc: The Honorable Sherwood Boehlert

SCIENCE AND MATHEMATICS

TEACHER RECRUITMENT AND RETENTION

Salary and Other Factors Affecting the Quality of the Teaching Workforce

January 1989

A report to the House Committee on Science, Space, and Technology and the Senate Committee on Labor and Human Resources in response to HR2330 (100th Congress)

SCIENCE AND MATHEMATICS TEACHER RECRUITMENT AND RETENTION
Salary and Other Factors Affecting the Quality of the Teaching Workforce

A report to the House Committee on Science, Space, and Technology and the Senate Committee on Labor and Human Resources in response to HR2330 (100th Congress) which requires the Director of the Foundation to...

> "...submit a report on the impact of salary levels on the recruitment and retention of science and mathematics teachers at pre-college levels. The report shall gather and analyze data from across the country and shall include case studies of school systems in which salaries have been changed to attract and retain science and mathematics teachers." (p.7)

Executive Summary

This report is predicated on four well-documented assumptions.

- Teachers are essential and central to the provision of quality K-12 education in mathematics and science.
- Recruiting and retaining high quality teachers who have the requisite scientific and mathematics knowledge and the ability to promote active student learning in these fields is of the highest importance given the continuing shortage of mathematics and science teachers and the past difficulty in attracting such individuals to the teaching profession.
- Beginning and career-path salaries are a fundamental and important ingredient in science and mathematics teacher recruitment and retention. As the Carnegie Forum report entitled A Nation Prepared: Teachers for the 21st Century suggests; to attract competent people who are above average in ability, "... districts will have to pay salaries at least equal to those offered in the mid-range of the wage scale for occupations requiring comparable education, roughly equivalent to what accountants are paid today."
- Salaries are important, however they are not sufficient. Occupational status, opportunities for professional development, and the professional conditions of schools and careers are also important for recruiting and retaining effective teachers.

In sum, teaching careers must offer opportunities for advancement --both financial and professional-- and schools must be professionally engaging places to work if competent science and mathematics teachers are to be recruited and retained.

Teacher Salaries -- problems -- A striking factor vis-a-vis the effects of salaries on teacher recruitment and retention is the relative salary opportunities in other employment arenas. The "opportunity costs" of going into teaching are significant for academically successful students. For physical science and mathematics majors, in particular, those costs are more severe.

The current structure of teachers' salaries makes recruitment of teachers in high demand disciplines, such as those in mathematics and science, persistently difficult. That is, potential teachers with the most financially rewarding career alternatives are faced with a salary structure in which teachers of different subjects are paid via the same salary schedule and most teachers reach the top of the salary scale in 10 to 12 years. In addition to these constraints, beginning teacher salaries are not competitive even with the middle range of other professions requiring a similar education and professional preparation investment.

Finally, financial rewards in teaching are tied to longevity and increased education. However, the most significant financial rewards, for those who stay in public education, go to those who leave teaching for administration or out-of-school staff positions.

What is being done? Over the past five years, average teacher salaries have been increased and states and localities have increased beginning or minimum salaries. Between 1981-82 and 1985-86 average teacher salaries went from $21,600 to $26,100. In 1987, thirty states had minimum salary floors and 19 states had a statewide salary schedule.

A few states, and some local districts, have initiated performance or "merit" pay plans. For such programs to succeed, the performance criteria on which salary increments are based must be established, but this is difficult for teaching. Consequently, teachers often view the evaluation procedures as invalid.

Career ladder plans have also been tried. Unlike merit pay, career ladders are designed to reward teachers not only for outstanding teaching, but also for taking on more job responsibilities and participating in professional development. Thus, career ladders are designed to encourage teacher retention by increasing both the monetary and non-monetary awards of a teaching career. Such plans have been espoused by numerous recent reports (e.g., Holmes report, 1986; Carnegie Forum, 1986).

In recent years, faced with persistent shortages in some teaching areas, particularly science and mathematics, a small number of school districts have implemented various forms of differential pay in order to attract teachers into these specialties. The structure of these incentives varies across districts. The incentives differ in their costs to districts and their effectiveness at eliminating shortages.

Five districts that have tried some form of differential pay include Houston, Boston, Hartford, Dade County, and Detroit. Although not implementing a differential pay plan, Rochester is included as an example of a district improving salaries. Houston has a plan which includes end-of-year stipends, $1500 each, for mathematics and science teachers. Boston has a matching salary program where by new teachers may be placed higher on the pay scale than their experience would dictate. The level of enhanced pay often exceeds $5000 annually. Hartford has a similar program, but currently neither mathematics nor science is designated as a shortage area.

Dade County, Florida has a program which includes a $1000 first year bonus for new teachers in shortage areas (including mathematics and all sciences). Finally, Detroit reported that they had implemented a program giving higher step levels to incoming teachers in 1986-87, but the program had been terminated this year. Rochester, on the other hand, has introduced a broader plan to enhance teaching status, improve salaries over the professional life of a teacher (including a lead teacher salary of $70,000) and provide opportunities for teachers without forcing them to leave the profession.

Professional Conditions of Teaching -- problems -- Salary structure and differences in outside income opportunity alone do not explain science and mathematics teacher recruitment and retention problems. Teacher attrition is strongly related to the conditions under which teachers work. Therefore, explanations of teacher shortages need to include professional conditions as a key factor along with salary levels.

Teachers find several aspects of their working conditions unsatisfactory; nonteaching duties, paper work and a loss of professional status were the most frequently mentioned inducements for leaving teaching. The loss of professional status included the following factors: a decline in the time available for instructional planning, a loss of autonomy and decision making control, and a loss of public respect.

Opportunities for professional development that include keeping up to date in the science or mathematics field of teaching and in innovative ways to help students learn is also critical in the retention of science and mathematics teachers. School districts' professional development efforts are inadequate for teachers. Most of their offerings do not deal with subject matter and are offered too infrequently to produce any noticeable impact on the teachers. Few opportunities are offered as a part of the work day of teachers--conditions taken for granted in many other professions.

What is being done? Procedures used in the day-to-day operation of schools frequently constrain teachers' effectiveness. These aspects of teaching are the targets of new initiatives in many states. Intended to address teacher shortages and quality by improving the preparation of teachers and the professional conditions of teaching, these programs include strategies to reduce teacher isolation, increase teachers' input into instructional decision making and encourage collegial problem solving.

Many states and districts are considering or implementing induction or internship programs for beginning teachers. This is an important departure from the traditional sink-or-swim approach to beginning teaching. Sustained induction is necessary to stem the high attrition rates of new teachers.

One of the major impediments to teachers professional growth and skill development is teacher isolation. Current efforts are underway to restructure schools so they increase time for collective teacher planning, preparation, and problem solving.

What Needs to be Done? -- The design of the American educational system requires that improvements in the recruitment and retention of high quality mathematics and science teachers must take place at the local and state levels. The magnitude and nature of quality teaching problems dictate that a comprehensive and systemic approach needs to be taken. This is particularly important in large urban districts where programs can be fragmented without specific efforts to coordinate them.

States need to consider the importance of salary and the professional conditions of schools and careers on science and mathematics teacher recruitment and retention.

The National Science Foundation is, through its programs, able to assist states and local districts in their teacher recruitment and retention efforts. While the Foundation is not in a position to provide operating support or salary resources, it provides support for efforts in teacher preparation, enhancement, recognition, and professionalization initiatives.

Improving Urban Science and Mathematics Education -- The growing need for mathematics, science, and technology education, and the growing proportions of minority groups in our national demographics, make it urgent for the National Science Foundation to address the needs of urban schools where large numbers of minority students attend. NSF's teacher enhancement and materials development programs are already active in city schools. Future projects can tie together these activities in a more complete manner.

NSF will be responsive to comprehensive, systemic urban initiatives which might include groups of scientists and mathematicians working with educators to provide teachers with technical assistance in the design and development of school-based professional development and training efforts. Simultaneously, education scholars would collaborate with school-based faculty and staff in projects to improve professional conditions at the school.

Successful systemic improvements should integrate science and mathematics improvement with broad reform efforts. NSF has initiated some of these activities through its Science and Engineering Education programs. Future systemic efforts will be in a position to use what has been supported and tie the following discrete efforts together:

- redefine the learning outcomes essential for a K-12 science and mathematics education;
- experiment with alternative approaches to staffing science and mathematics teaching;
- increase teacher participation in designing the math/science curriculum and selecting materials;
- improve the content knowledge and skills of teachers; (professional development)
- experiment with alternative teaching arrangements, organizational structures, and decision making procedures.

State Science and Mathematics Education Improvement -- Governors, legislators, and chief state school officers, working together with scientists, mathematicians, and educators, are in a strategic position to develop and implement a comprehensive set of science and mathematics education improvements. Comprehensive state initiated policies and program incentives for the improvement of school-based K-12 science and mathematics education are needed. Such programs should be designed to make teaching an attractive career for individuals who have strong backgrounds in science and mathematics. Such programs, consistent with or in support of local initiatives, should include efforts to:

- examine and initiate appropriate state policies and practices related to the recruitment and\retention of science and mathematics teachers.
- improve preparation and induction of new science and mathematics teachers.
- provide incentives for school districts to support school-based improvements which enhance the professional conditions for teachers and their careers.
- change regulations that impede sound curricular and teaching practices .
- support staff development and technical assistance to local schools.
- promote local school decision making on the part of the teachers.

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SCIENCE AND MATHEMATICS TEACHER RECRUITMENT AND RETENTION
Salary and Other Factors Affecting the Quality of the Teaching Workforce

A report to the House Committee on Science, Space, and Technology and the Senate Committee on Labor and Human Resources in response to HR2330 (100th Congress) which requires the Director of the Foundation to...

> "...submit a report on the impact of salary levels on the recruitment and retention of science and mathematics teachers at pre-college levels. The report shall gather and analyze data from across the country and shall include case studies of school systems in which salaries have been changed to attract and retain science and mathematics teachers." (p.7)

Introduction

Teachers are central to the education quality of the 45 million elementary and secondary education students in the United States. In sum, the quality of individuals attracted to teaching, in terms of what they know and are able to do, is a central issue directly related to successful learning in schools.

The beginning and career salary for science and mathematics teachers have acted as important constraints on recruitment and retention. As the Carnegie Forum report entitled A Nation Prepared: Teachers for the 21st Century suggests, to attract competent people who are above average in ability, "... districts will have to pay salaries at least equal to those offered in the mid-range of the wage scale for occupations requiring comparable education, roughly equivalent to what accountants are paid today." The overwhelming majority of all teachers are paid on the basis of a single salary schedule. Separate data on science and mathematic teachers' salaries is often not available; therefore, understanding the recruitment and retention of science and mathematics teachers will take more than an analysis of the effects of base pay.

Several districts have experimented with flexible salary schedule arrangements for recruiting teachers in shortage areas. Other districts have sought creative ways for science and mathematics teachers to gain additional income. However, even in districts and states which have experimented with differential salary incentives, shortages of mathematics and science teachers persist.

Putting salary into perspective vis-a-vis recruitment and retention not only requires a review of the evidence related to actual salary levels (beginning and career path), but also to outside (of teaching) income opportunities for different types of teachers and nonremunerative incentives for entry and retention into science and mathematics teaching.

Two such important factors form critical constraints on school systems' efforts to recruit and retain science and mathematics teachers. First, these teachers, particularly mathematics, physics, and chemistry teachers, have a viable set of alternative nonteaching careers in the public and private sector. Second, secondary mathematics and natural science teachers are strongly oriented to the content of the science and mathematics disciplines. These individuals seek careers that offer the professional excitement and personal satisfaction derived from the scientific process which, if denied, act as a disincentive to the teaching career choice.

PUTTING SALARIES INTO PERSPECTIVE

Salaries are a necessary and important ingredient in the recruitment and retention of science and mathematics teachers. However, they alone are not sufficient. Occupational status, opportunities for professional development, and the professional conditions of schools and careers are just as important (Darling-Hammond, Hudson, and Kirby, 1988; Carnegie, 1986; Holmes, 1986; Darling-Hammond and Hudson, NSF 1987; Rosenholtz and Smylie, 1984; National Governors' Association, 1986). Schools must be professionally engaging places to work and teaching careers must offer opportunities for advancement if school systems are able to attract and keep competent science and mathematics teachers.

To understand the effects of salaries on teacher recruitment and retention, "teacher shortages" must be considered since in the aggregate such shortages are a manifestation of inadequate recruitment and retention policy and practice in these areas. Although the evidence on teacher supply and demand is weak and fraught with definitional problems, school district reports and actions taken to staff science and mathematics classes with less than qualified teachers indicate a persistent shortage of natural science and mathematics teachers over the past 12 to 15 years.

The evidence indicates that the intensity and distribution of these shortages vary over time; however, the pattern persists even when there is a relative low general demand for teachers.

Teacher salaries generally follow the market, rising in times of demand and falling in times of surplus. However, the income alternatives outside of teaching and the constraints on nonremunerative incentives combine to make science and mathematics teachers recruitment and retention problems more difficult than they are for most other instructional areas. These difficulties vary within the fields of science and mathematics, among various levels of teaching, and in different locations.

Targets of Recruitment and Retention - Issues of Quality and Quantity

The targets of recruitment and retention are individuals motivated not only by science and mathematics but also by the opportunity to share their excitement and knowledge with students. Recruitment of science teachers must consider the unique needs of individuals with scientific interests.

Teachers highly motivated by an appreciation for science and mathematics as well as by working with students are the same individuals who expect opportunities to expose students to laboratory work and who have attractive alternative career choices. They need the laboratory for personal enjoyment and professional development. In sum, the individuals we need most demand the most of their teaching experience. If schools are unable to meet their needs, they are likely to pursue other employment that does.

The Science and Mathematics Teacher Quality Issue. There are many definitions of teacher qualification. For example, qualification and certification are not necessarily synonymous. For purposes of this report, the definition of quality is directly related to what teachers know (science and mathematics) and are able to do (pedagogy, instructional program development, decisions regarding learning, and so on). These two fundamental quality issues give rise to the following questions:

a) Does the the individual have adequate disciplinary knowledge to explain scientific and mathematical principals, concepts and phenomena in a variety of ways?

b) Is the individual able to teach by drawing upon a variety of learning strategies which engage student interest; and

c) Is the individual able to cogently respond to students questions, problems, and understandings (or misunderstandings)?

These considerations place central importance on quality issues with regard to teacher recruitment and retention. These issues overshadow the quantity issue. That is, are there enough teachers to staff science and mathematics classrooms? Quantity issues are important in their own right. However, the core problem for the nation is the knowledge and ability of teachers that fill science and mathematics classrooms.

Even if there is no shortage of individuals who currently have the minimum credentials to teach, there is a major shortage of **well qualified science and mathematics teachers**. This problem is particularly acute at the elementary school level and in urban centers (Darling-Hammond and Hudson, 1987).

This problem is related to school system responses, limitations of supply, and constraints on inducements to enter or stay in teaching. The history of science and mathematics course staffing is riddled with emergency hiring, out-field-teaching, the use of full-time substitutes, and, in secondary schools, canceled courses.

As mentioned, the problem differs for different fields, in different locations (urban core, isolated rural areas) and at different levels. That is, physics and chemistry differ from biology and general science. Schools in the urban core and isolated rural areas have much more severe recruitment and retention problems than suburban and independent city districts. Upper level mathematics teachers are harder to recruit and retain than lower level and general mathematics teachers.

Elementary "common branch" teachers (responsible for all core academic courses in a single classroom) have, on average, the weakest academic backgrounds in science and mathematics among all teachers assigned to teach those subjects. Recruiting scientifically and mathematically educated elementary teachers is a major problem for all school systems.

FACTORS NECESSARY TO RECRUIT AND RETAIN HIGH QUALITY TEACHERS OF SCIENCE AND MATHEMATICS

Successful recruitment and retention of highly capable and motivated science and mathematics teachers must address both salary and professional issues.

SALARY

Salary Structure. It has been argued (Kershaw and McKean 1962; Levin 1985) that shortages of mathematics and science teachers are an expected and predictable outcome of the salary structure for teachers. That is, shortages can be expected when different types of teachers are paid similar salaries, but some have persistently higher alternate income opportunities. Since the 1950's, all teachers have been on similar salary schedules that pay different types of teachers similar wages based only on years of teaching and educational attainment.

As indicated above, this constrained salary hypothesis fits the data which shows persistent science and mathematics teacher shortages over the last 15 years. Such shortages persist even during times of general decline in teacher demand. During times of falling demand, all teacher salaries fell, maintaining the relative shortage of mathematics and science teachers.

There are abundant data to document the higher income opportunities of individuals trained in the mathematics, engineering and science areas. (Darling-Hammond and Hudson 1987, Lewin 1985, NCES 1987, National Science Board 1987). Murnane (1987) provides time series data which shows that between 1971 and 1985 starting salaries for mathematics, physics and chemistry students were 40 to 60 percent higher than starting salaries for teachers, whereas starting salaries for biology majors were only 10-25 percent above teaching salaries. For the humanities, the salary differential was between 5 and 20 percent.

Salaries Are Not Enough. One piece of evidence that does not corroborate the effect of higher outside income opportunities is the different attrition effects among science and mathematics teachers. Science teachers leave their jobs at significantly higher rates than other teachers (Murnane and Olsen, 1987; Murnane and Olsen, 1988; Grissmer and Kirby (1986); Holmes et al, 1988).

However, the data show some important distinctions between different types of science and mathematics teachers.

Biology teachers tend to have both lower attrition and lower outside income opportunities than either chemistry or physics teachers. Biology teachers fit into the framework of the theory. However, surprisingly, mathematics teachers do not follow the expected pattern. Outside wage opportunities are as high for mathematics majors as for chemistry and physics majors; however, their long term attrition is significantly lower than that of science majors. Indeed, the attrition rate for mathematics teachers in several states studied were equal or lower than that of the average secondary school teacher.

This finding may be partially explained by the fact that mathematics teachers may not be a homogeneous group, and may have higher or lower outside opportunities depending on whether they teach advanced courses or lower level courses. Another explanation is that teaching conditions peculiar to science may account for differences in leaving rates. One key difference is that science teachers may be more sensitive to the quality of laboratory equipment, and the associated responsibility for conducting laboratory courses. Therefore, the professional environment of schools may play an important role in explaining differences in mathematics and science teacher attrition rates.

If differences in outside income opportunity were the sole reason for problems in teacher recruitment and retention, then one would expect no shortages in special education teachers, no differences in attrition among mathematics, physics and chemistry teachers, and no salary differentials in schools with different teaching conditions. These central features of teacher shortages cannot be explained by outside wage opportunities.

Both working conditions and outside wage opportunities play some role. The alternative wage theory does seem to explain a significant part of the shortage of physics and chemistry teachers, and the somewhat lessor shortages of biology teachers. However, any overall theory that attempts to explain teacher shortages needs to include working conditions as a key hypothesis along with salary levels.

Higher Salary Levels. It is important to identify and measure, to the extent possible, what is gained from teacher pay increases. Teacher pay increases are directed toward improving the performance and productivity of the teaching profession in specific ways. These effects are:

- increasing the supply of individuals seeking teaching jobs
- retaining current teachers
- motivating teachers to undertake activities which improve their performance
- increasing the turnover of teachers with marginal performance
- retaining the stability of the teaching workforce (e.g., avoiding labor disruptions)

Higher teacher salaries, with respect to alternate occupational choices, will of course increase the supply of individuals <u>into</u> teaching. This supply increase will occur at all levels of teacher quality. Studies of teaching and in another occupational areas generally provide evidence that higher pay brings larger expansion in lower quality occupational groups.

Higher salary alone will not result in a higher quality teacher workforce. If school districts cannot distinguish, at the point of hiring, differences in higher and lower quality teachers, then higher salary will not result in improved quality being hired. However, if school districts are selective, then the expanded number of higher quality teachers can be hired, and lower quality teachers will be screened. This ability to screen out lower quality teachers is an important consideration in managing increased teacher supply.

Higher teacher salaries also will increase retention of present teachers. An important question is whether the retention increases are larger for higher or lower quality teachers, and whether school `districts take advantage of the higher retention to increase turnover of lower quality teachers and/or reduce the number of lower quality new hires. If no pruning of lower quality teachers occur and if selectivity at entrance is poor, then the effects of pay increases can be seriously weakened.

A final effect of pay increases is to increase the performance of current teachers. There is no research on the extent to which higher salary induces teachers to improve their own performance. It is unlikely that higher salaries alone will have a major impact on day-to-day teacher performance. However, to the extent that higher salaries allow and motivate investment in more education, teacher performance may be improved over the long run, provided that the investment is in the areas directly related to improved teaching and learning.

The incentive for teachers to enhance their own performance can also depend on the structure of teacher pay. If pay increases are based strictly on years of experience, then incentive for improved performance must all come from intrinsic motivation and other noneconomic reasons. Pay systems which provide differential pay based on some criteria of performance or participation in performance-enhancing activities have both intrinsic and extrinsic motivation for improving performance. The common current practice is pay based on years of experience and education. Extrinsic motivation is provided to pursue advanced degrees, although the small pay differentials between bachelor's, master's, and PH.D degrees mean that the return from the educational investment currently is small.

Differential pay for teachers in the form of merit pay is meant partly to provide additional motivation for improving performance. To the extent that evaluation criteria and procedures can identify better teachers, and significant compensation differentials are established, this is possible. To the extent that evaluations are considered unfair or arbitrary, then differential pay can actually result in lower morale and degraded performance. The evidence on such schemes is weak. Many end before they have a chance to be assessed. Such schemes, when assessed, are of short duration due to financial problems in the school district or because the modest differentials seemed to have no effect vis-a-vis negative side effects.

Differential pay can also be used to improve the quality of the teaching pool. That is, science and mathematics teachers can be provided with salary supplements for performing additional duties or for summer work without leaving the teaching profession. For example, career ladder schemes offer additional pay and status for teachers who engage in curriculum development, mentoring beginning teachers, and leading a cross-disciplinary teaching team. Some school systems have arranged for summer employment in science rich settings to increase income and provide stimulating enrichment opportunities for science and mathematics teachers. Most of these schemes are too early in their implementation phase to evaluate; however, there is some anecdotal evidence that they are having a positive effect on retention (Grissmer and Kirby, 1987).

The effects of pay increases on teacher attrition -- some research evidence. The attrition rate for teachers follows a U-shaped pattern at the state level (Grissmer and Kirby, 1987) with attrition rates in the first few years being between 10 and 20 percent, falling to well below 5 percent during mid-career and rising again to 10-20 percent after retirement eligibility, usually at age 55. Attrition among teachers is accounted for by those leaving the profession and not returning, those taking temporary leave who return, and those leaving to teach in another state. Although the proportions in these groups can vary over time and between states, approximately 1/3 or fewer of those leaving each year will not return to teaching, about 1/2 or more will leave temporarily, and 1/4 or fewer leave to teach in other states.

Pay increases will differentially impact teachers at different points in their career. Pay increases will have their largest effect on teachers during their first 5 to 10 years of teaching experience. This is because individuals at this time of their career have the most competitive outside opportunities and it is the easiest time to switch careers. They also do not have much investment in pension or retirement systems, and fewer have made a commitment to teaching. Once past 15 years of teaching, few teachers leave partly because of retirement vesting, partly because of a higher commitment to teaching, and partly because switching careers is harder at this point in their career. Thus pay increases will have only small effects on this group.

Several studies indicate that teachers with stronger academic backgrounds tend to leave teaching at higher rates than those with weak academic records (Murnane, 1987, Murnane, 1988, Schlechty and Vance, 1981). Some of these studies have speculated that such individuals with strong science and mathematics backgrounds have a higher commitment to teaching than for those who enter because of pay. The fact that they seem to leave faster than other teachers is likely to be due to factors other than salary, e.g., professional opportunities, working conditions, opportunities to learn on the job, and so on.

Another important question concerning pay increases is their relative effectiveness in preventing attrition compared to other policies. Expenditures on improved working conditions, laboratories, and staff support all can aid in lowering attrition. The key resource allocation question is the extent to which such expenditures are more or less cost effective in preventing attrition as opposed to direct pay increases. An alternate question is the relative effectiveness of resources allocated to fringe benefits, retirement benefits or reduced working schedule as opposed to pay increases.

State Case Studies. There have been few attempts to address the key questions involving the effectiveness of pay in preventing teacher attrition. The most recent and sophisticated work to examine the career patterns of teachers and the effects of pay on these career patterns is work that uses state longitudinal data files in Michigan and North Carolina to track entering teachers (Murnane, Singer, Willet, 1988; Murnane, Olsen, 1988; and Murnane, Olsen, 1987).

Michigan. Survival and re-entry rates of cohorts of teachers entering teaching in Michigan during two time periods 1972-1974 and 1978-1980 were studied using teaching specialty and demographic characteristics as variables (Murnane and Olson 1987).

Teachers are grouped into subject-specific categories: elementary, english, mathematics, social studies, biology and chemistry/physics. The "first spell" of teaching --length in years of continuous teaching before at least one interruption-- were analyzed with the following results:

- Preliminary estimates indicate that salary had a small, but statistically significant effect on survival rates for later, but not for earlier cohorts. The earlier effect was small-a $1000 salary increment would raise probability of teaching to five years by only 2.7 percent.
- 52 percent of teachers beginning in the early 1970's were teaching in their eleventh year. Approximately one-quarter of this group still teaching had at least one interruption in teaching.
- Attrition of teachers is much higher in earlier years than later years.
- For those with a career interruption, approximately 2/3 were absent for only a year. Surprisingly, the pattern of career interruptions were similar for men and women. Career interruptions were often accompanied by district changes, e.g., student population shifts, with district changes more likely the longer the interruption.
- Cohort survival rates for uninterrupted teaching was much lower for cohorts entering in the late 70's compared to the early 70's. Only 45 percent in

the later sample taught for five years compared to 61 percent for the earlier sample, although more of the later sample returned.

- Survival rates depended on subject taught with chemistry, physics and foreign language teachers having survival rates of 40 percent through eleven years and elementary, special education, mathematics, social studies and english having survival rates of 50 percent.
- Chemistry and physics have much lower return rates given an interruption in teaching. Only 1/9 of chemistry and physics teachers still present after 11 years were returnees compared to almost 25 percent for the entire sample. Some specialties had much higher return rates. In contrast to the chemistry and physics teachers, 40 percent of the foreign language teachers were returnees.
- Differential survival rates for different subject specialties had a much larger spread for the later cohorts. This is primarily due to certain groups like chemistry/physics having substantially lower survival rates in the later cohort.
- Teachers entering the Michigan system were much more likely to stay if they entered at a later age. Teachers entering at 32 have a 7.5 percent higher probability of staying five years than one entering at age 22.

The authors point out that the time period for the analysis, a period of rapidly declining enrollment and involuntary teacher terminations, may make any results not generalizable to other states or time periods. In fact, the large variation in survival rates by cohort shows that teacher layoffs may have had a large impact on teacher survival rates. These result may change during times of expanding enrollments. Between 1975 and 1985, enrollments in Michigan dropped by 18.5 percent compared to 11.8 percent nation-wide. Michigan had strong outmigration trends due to the poor economy in the auto industry.

The Michigan results may represent an extreme condition in a school system of rapidly declining enrollments and poor economic conditions. The effects of salary on survival may be particularly sensitive to the presence of these conditions. The declining enrollments put pressure for teacher layoffs, but layoffs would be made difficult by the poor economy. Thus it is likely that teacher unions and school districts would trade off job security and salary increases in this period. These trade-offs would make measurement of the effects of salary extremely difficult.

Teaching specialty and gender variables were also analyzed. Since elementary teachers are predominantly female, while high school teachers- especially those in science and mathematics- are more often male, it is important to sort out survival behavior by both gender and specialty. Their results show that for these cohorts specialty specific effects change markedly if gender is included in the analysis. The results show that both gender and age at entry influence first teaching spell. Young women have the shortest spell of first teaching followed by young men. Both older (>31) men and women have the longest first teaching spell. The proportion of teachers still continuously present after 12 years of teaching is approximately 30 percent for young women, 50 percent for young men, 60 percent for older men and 65 percent for older women.

Approximately 30 percent of teachers with an interruption return to teaching- most within one year. These return rates are slightly higher for young women, but these return rates do not significantly affect the differentials in the total survival rate. The specialty specific effects controlling for age and gender show that chemistry/physics teachers have markedly lower continuous survival. Continuous survival rates through 12 years for a typical young female physics teacher is approximately 15 percent compared to 34 percent for a similar elementary teacher. Biology and mathematics female teachers have 25-30 percent survival rates. Moreover, chemistry/physics teachers have much lower return rates (13 percent) compared to elementary (32 percent) and mathematics (25 percent) or biology (24 percent) teachers.

This analysis shows that it is essential in the analysis of science teachers to include gender. Here the effects of the specialty were underestimated if gender is not included. This is due to the fact that more science teachers are men, and in these data men had higher survival than women.

Differences by specialty are hypothesized to occur because of differing outside wage opportunities of different types of teachers. Those individuals with scientific or mathematical skills usually have higher outside opportunities than do other teachers. This pattern tends to be confirmed for chemistry/ physics teachers and biology teachers. For instance, physics/chemistry graduates are among the highest paid of college graduates, while biology majors do less well, although still better than humanities majors. Survival rates for different teacher types seem to reflect these outside opportunities. However, mathematics majors also have high outside opportunities, but their survival rates in Michigan were among the highest. As pointed out above, these differences can be explained only by a theory of teacher attrition that includes professional conditions of schools and nonremunerative rewards and/or the possibility of differences within the population of mathematics teachers (e.g., unanalyzed differences in lower and upper level mathematics course teachers).

North Carolina. The analysis of the North Carolina data (Murnane and Olson, 1988) is the most ambitious and relevant attempt to measure pay effects for teachers. These results may be more generalizable than those from Michigan. North Carolina had neither large enrollment declines nor a drastically changing economy which affected tax revenues dramatically. Thus North Carolina may be more typical of other states, especially those states with growing populations where shortages are more likely to occur. In addition, National Teacher Examination (NTE) test score data were available, allowing for some assessment of the effects for teachers with different levels of success in taking the test.

The patterns from simple survival data in North Carolina are similar to those found in Michigan. In particular, mathematics teachers in North Carolina also have significantly higher survival rates than physics or chemistry teachers. Using first teaching spell as the primary variable, the results dealing with pay and ability classes include the following:

- Pay increases had a statistically significant effect on attrition and a differential effect on those in the upper and lower quartiles. A $1000 raise in pay in constant 1967 dollars would increase median duration of the initial stay in teaching by 2 or 3 years. However, this effect measured for cohorts entering in the earlier 1970's declined for later cohorts.
- Pay effects were larger for lower ability teachers than for higher ability teachers. Pay effects were approximately 30 percent less for teachers in the upper quartile than for lower quartile teachers.
- There is some indirect evidence that higher salary is provided to compensate for poor working conditions.
- Physics and chemistry teachers had the lowest survival rates of all types of teachers, with biology and general science teachers having somewhat lower survival than average teachers, but mathematics teachers had survival rates at or above the average teacher.

- Controlling for other factors, teachers in the upper quartile of NTE scores leave at significantly higher rates than those in the bottom three quartiles. Predicted continuous survival rates for biology teachers 10 years after entry were approximately 17 percent for upper quartile and 38 percent for the lower three quartiles.
- Physics and mathematics teachers had 10 year survival rates of approximately 18 percent compared to around 40 percent for all high school teachers.

PROFESSIONAL CONDITIONS OF SCHOOLS AND CAREERS

Rosenholtz and Smylie (1984 review of research) found that teacher attrition is most related to the conditions under which teachers work. Specifically teacher attrition is strongly affected by those conditions that undermine the teachers's ability to do an effective job of teaching. Salaries were generally found to be a significant, but less important, factor contributing to the attrition of those who had already entered teaching (see also Chapman, and Hutcheson, 1982; Bredeson et al., 1983; Litt and Turk, 1983). Thus, attempts to increase teacher retention --and at least indirectly teacher recruitment--may be best targeted toward policies that improve teachers' working conditions, rather than just toward compensation increases.

The professional conditions under which teachers' work are unique in many ways. They have peculiar rewards (e.g. working with young people, summer vacations, and nine-month contracts), drawbacks, and disadvantages. Teachers' reports of their working conditions, specifically on the reasons they have left (or have considered leaving) teaching, suggest that teacher retention could be improved by changing certain features of the teacher workplace and/or teacher job responsibilities.

One source of data on the working conditions that teachers find unsatisfactory comes from the National Education Association Survey on the Status of the American Public School Teacher (NEA, 1987). One question on this survey asks teachers "What in your present position as a teacher hinders you most in providing the best service of which you are capable?" Comparable data collected in 1976, 1981, and 1986 reveal a remarkably consistent set of selected responses: incompetent and uncooperative adminstration, student discipline and attitudes, lack of materials and resources, heavy workload and extra responsibilities, and, in the latter two years, lack of funds and decent salaries.

The latter two years (1981 and 1986) also differ from 1976 in that, in both of these latter years, "heavy workload and extra responsibilities" was the most frequently mentioned hindrance to teaching. In fact, the same survey shows that the average number of uncompensated hours that teachers spend on school-related activities increased over two hours per week from 1976 and 1981 to 1986. This finding suggests that the educational reform movement that began in the late 1970s, with its emphasis on student testing, administrative control of teaching, and educational accountability, has had the undesirable effect of increasing teachers' "clerical" burden.

Other surveys, as well as interview data, corroborate the prevalence and severity of this negative aspect of teachers' work. The Metropolitan Life Survey of Former Teachers in America (Metropolitan Life, Harris and Associates, 1987), for example, found that the most common reasons ex-teachers gave for leaving teaching were inadequate salaries (60 percent), poor working conditions (36 percent), and student- and administrator-related problems (30 percent each). Among working conditions, nonteaching duties and paperwork were the most frequently mentioned inducements for leaving teaching. Comparable results were reported for teachers who had considered or are considering leaving teaching.

Finally, Cohn et al. (early 1980's undated) conducted an interview study of teachers in Dade County/Miami schools in Florida. Although not a nationally representative sample of teachers, the data are still informative, since respondents are not constrained or otherwise biased by a predetermined set of response options. In this study, teachers listed the following factors as those that discouraged them the most from remaining in teaching: student lack of motivation and parent apathy (which teachers often perceive as causally related), and a loss of professional status. The latter was a catch-all for the following factors which impeded teachers' efforts to function as independent experts: increased paperwork, with a subsequent decline in time available for instructional planning, loss of autonomy and decision-making control (largely due to increased central office control over instruction), and a loss of public respect.

By analogy, if the working conditions that teachers dislike contribute to teacher attrition, then those conditions that they like can minimize attrition, or help to counteract poor working conditions. Two surveys are relevant: NEA (see above) which also asks teachers about factors that help them in their teaching efforts and a Teachers College, Columbia University (Zumwalt 1982) survey of New York City teachers. The latter survey, although not using a representative sample, has the advantage of using an unconstrained, open-ended format.

The NEA data on aspects of teaching work that are most helpful to teachers revealed fairly consistent results for 1981 and 1986. In both years, two of the three most important factors were interest in children and teaching, and cooperative and competent teacher colleagues. Help from administrators and specialists also ranked high in both years. Finally, the teacher's training, education, and knowledge of subject matter was also viewed as a help, as was "the school environment and freedom to teach". Similar factors were also rated highly in the 1976 survey, although the order of responses differed more.

The Teachers College survey, examining the factors which help teachers maintain positive attitudes about their jobs, found four general "subthemes":

- the freedom to be creative and innovative;
- the ability to influence students;
- opportunities for recognition and support from students, colleagues, administrators, and parents; and
- collegiality and the sharing of expertise.

These surveys suggest that the following changes in teachers working conditions are likely to help reduce teacher attrition.

Administrative support and buffering. The support of administrators is obviously crucial to teachers satisfaction with their job. The survey data show that administrators can be one of the best and one of the worst features of teachers' work environment. Administrative support involves more than just positive employer-employee relations. It also involves what is commonly known as "buffering," that is, active efforts to structure the school environment to maximize teachers' opportunities and ability to provide effective instruction.

Thus, administrative support eliminates or minimizes many of the factors that discourage teachers (paperwork, nonteaching duties, discipline problems, lack of materials). It also emphasizes and encourages those conditions that teachers find most rewarding in their efforts to reach students (adequate preparation time, clerical support, uninterrupted class time, clear instructional goals, etc.).

A collegial work environment. Colleagues are never perceived as an inducement to leave teaching, but they are usually viewed as a positive feature of the working environment. In fact, other researchers note that collegial relationships also characterize effective schools (Little, 1982), and contribute to teacher efficacy, a prime determinant of teacher satisfaction (Rosenholtz and Smylie, 1984).

In collegial settings, experienced teachers profit from opportunities to assume new challenges and leadership roles, while less experienced teachers profit from the technical assistance provided by their veteran colleagues (Rosenholtz and Smylie, 1984; Walberg and Genoa, 1982; Ashton et al., 1983). These opportunities for leadership and professional recognition seem to enhance the retention of effective, experienced teachers (Rosenholtz and Smylie, 1984; Chapman and Hutcheson, 1982; Stark et al., 1980).

Reducing extraneous nonteaching duties. Teachers obviously enjoy teaching; most of their motivation for entering and remaining in teaching comes from the intrinsic satisfaction they find (Rosenholtz and Smylie, 1984). Thus, teachers are discouraged by working conditions that reduce the time for teaching, reduce their ability to "reach" students, or increase the amount of nonteaching duties.

Maximizing the time that teachers can spend teaching while minimizing the time that they spend in nonteaching tasks is therefore a likely way to encourage teachers to remain in the field. Some ways of increasing teachers' opportunities to function as teachers include: the hiring of more support staff (teachers' aides, clerical and secretarial staff) to assist teachers, reducing class sizes and course loads, and eliminating extraneous, over-burdensome accountability requirements.

OCCUPATIONAL STATUS

Occupational status that commands peer and public respect is directly related to teacher recruitment and retention (Darling-Hammond and Hudson, 1987). The ability to attract and retain individuals with knowledge of science or mathematics, is strongly influenced by the relative status of teaching vis-a-vis other occupations. Teachers as a profession are particularly sensitive to their occupational status. Efforts to enhance the occupational status of teachers will serve as a strong inducement for the recruitment of highly capable teachers and for their ultimate retention.

PROFESSIONAL DEVELOPMENT

Opportunities for professional development are also critical in the retention of science and mathematics teachers. These opportunities include keeping up to date in the science or mathematics field of teaching and in innovative ways to help students learn. Teachers in most K-12 schools are separated from colleagues teaching in the same subject matter field. This isolation, as well as the demands of the profession, rapidly remove them from the current developments in their field of interest in science or mathematics.

School districts' professional development efforts are inadequate for teachers. Most efforts do not deal with subject matter and are offered too infrequently to produce any noticeable impact. Many such efforts are one-shot institute days or after school workshops. Few opportunities are offered at the school site or as a part of the work day of teachers -- conditions taken for granted in many other professions and occupations.

WHAT IS BEING DONE?

Policy Options and Activities Being Implemented by States and Districts

Two general types of policy initiatives are typically developed to recruit and retain a sufficient number of high quality science and mathematics teachers -- and for other shortage areas (Hudson, 1988). One set of policies attempts to increase teacher supply by increasing the inducements to enter and to remain in teaching. These policies include increased teacher salaries, teacher induction programs, career ladder plans, and performance-based compensation plans, such as merit or pay-for-performance plans. Career ladder plans offer both remunerative and nonremunerative professional opportunities.

The second set of policies attempts to improve recruitment and retention efforts by lowering the costs or other barriers to teaching. These include student loans and scholarship programs, funds and programs for retraining teachers for certification in shortage areas, alternative certification and "nontraditional route" programs, and policies designed to lower barriers to reentry after a period of absence.

The former set of policies serves to increase both teacher recruitment and retention, while the latter serves only to increase recruitment; it does not (at least by intent) increase teacher retention. These policies also differ in the degree to which they can be used as an incentive for teachers in certain subject areas versus others. Generally speaking, incentives for teachers (salary increases, performance-based pay plans, induction programs) must be made available to all teachers within the system offering the incentive. In contrast, inducements offered to teacher candidates (loans, scholarships, alternative certification, etc.) are more easily offered exclusively, or to a greater degree, only in those subject areas where demand is highest, such as in science and mathematics.

State policymakers have responded vigorously to increase the supply of teachers, particularly in mathematics and science, or in shortage areas more broadly defined. Forty-nine of fifty states have considered such initiatives. And, most states have, or are considering, instituting more than one initiative. The status of state-level initiatives to recruit and/or retain teachers, as of 1986-87, is listed in Table 1 -- retraining programs are listed under financial aid programs and nontraditional route programs are listed under alternative routes.

Recruitment Policies at the State Level (See Table 1)

The most common of these initiatives are financial aid programs to train or retrain teachers. Thirty-nine states have such programs, and an additional three states are considering starting a financial aid program. In 28 of these states, funds are specifically targeted toward mathematics and science or "shortage areas" (which almost always include mathematics and science).

TABLE I

	RECRUITMENT INCENTIVES		RECRUITMENT AND RETENTION INCENTIVES		
STATE	Financial Aid Programs	Alternative Certification Programs*	Induction Programs	Salary Increases	Performance-based Pay Programs
ALABAMA	Forgivable loans, scholarships to recruit in m/s, retrain in shortage areas	Coursework for full certification; state approved LEA plan in shortage areas		All teachers	Performance-based incentive program
ALASKA	Forgivable loans to teach in rural areas				
ARIZONA	Forgivable loans	Recent B.A. program; coursework for certification		Recommended for beginning teachers	CL plan
ARKANSAS	Forgivable loans	Exam; coursework for certification		All teachers	CL plan
CALIFORNIA	Forgivable loans in shortage areas	LEA-IHE program in 10 districts	Mentor teacher program; considering "residency program"	Beginning teachers	
COLORADO	Scholarships	Exam, workshop, certification coursework	To be implemented in 1987		
CONNECTICUT	Forgivable loans in shortage areas	6-week program for recent B.A.s	Mentor teacher program; statewide induction program to begin in 1987	Beginning and experienced teachers	Funds for districts to develop career incentive plans
DELAWARE	Forgivable loans in shortage areas, scholarships to retrain in m/s	In shortage areas: exam, certification coursework		Beginning teachers	Career development awards
DISTRICT OF COLUMBIA		Certification coursework	Intern program		
FLORIDA	Forgivable loans to teach in rural or urban areas, or in shortage areas, retraining funds in m/s	Major, modified Beginning Teacher Program	Beginning teacher program	Recommended	Master teacher program replaced with district-developed incentive programs
GEORGIA	Loans in shortage and other areas	In shortage areas: 10 quarter hour credits, exams	Evaluation and support program	Beginning and experienced teachers	Piloting CL plan
HAWAII	Funds to cover course work in shortage areas, including retraining		Considering	All teachers	

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*Other requirements usually exist, e.g., major in subject area, supervised internship, demonstrated competencies.

NOTES: m/s = mathematics and science CL = career ladder

SOURCES: AACTE, 1987; College Board, 1986; SREB, 1986; U.S. Department of Education, 1987.

	INCENTIVE				
STATE	Scholarship or loan	Alternative Certification Route	Induction program	Salary increases	Career ladder/ merit pay
IDAHO		Considering	Piloting	Proposed	Initial monies appropriated for CL plan
ILLINOIS	Scholarships in shortage areas, forgivable loans to retrain in m/s		Piloting		State-funded district CL plans
INDIANA	Forgivable loans to recruit in shortage areas, retrain in m/s	Considering	Considering		Piloting incentive pay program
IOWA	Scholarship/forgivable loan program in m/s			Considering	Performance-based pay program
KANSAS		In shortage areas: certfication coursework	Piloting		Grants to LEAS implementing incentive programs
KENTUCKY	Forgivable loans to recruit and retrain in m/s; scholarships	In shortage areas: state-approved district plan	Exists	All teachers	Piloting CL program
LOUISIANA	Scholarships and forgivable loans (re)-proposed	General education requirements, exam			CL/school incentive plans
MAINE	Forgivable loans in shortage areas	Transcript analysis, remedial coursework	Piloting	Beginning and experienced teachers	Tiered certification
MARYLAND	Forgivable loans to recruit and retrain in m/s	Coursework: considering alternative preparation programs	Piloting		Career development incentives
MASSACHUSETTS	Forgivable loans in shortage areas	Modified internship; intern program being developed		Beginning teachers	Stipends for teachers who assume extra duties
MICHIGAN	Monies targetted toward m/s retraining				
MINNESOTA	Considering		Considering		
MISSISSIPPI	Forgivable loans to recruit and retrain in m/s	NTE, 12 credit hours in education	Being implemented		
MISSOURI	Forgivable loans	24 semester hours education	Being developed	Beginning teachers	State- or LEA-developed CL plans
MONTANA					
NEBRASKA	Forgivable loans to recruit, retrain in m/s	Test requirements	Considering	All teachers	

STATE	INCENTIVE Scholarship or loan	Alternative Certification Route	Induction program	Salary increases	Career ladder/ merit pay
NEVADA	Scholarships				
NEW HAMPSHIRE	Considering forgivable loans	Written and oral exams; in shortage fields, internship			CL program planned
NEW JERSEY	Forgivable loans	NJ Alternate Route: Exams, coursework, and supervision		Beginning teachers	Incentive programs; piloting master teacher program
NEW MEXICO		Several options	Being developed	Beginning and experienced teachers	CL plans being developed
NEW YORK	Forgivable loans		Piloting		Incentive pay plan
N. CAROLINA	Scholarships, forgivable loans	Enrollment in education program	As first year of career ladder		Piloting CL plan--includes merit pay
NORTH DAKOTA				Beginning teachers	
OHIO	Forgivable loans in shortage areas		Beginning in 1987	Beginning teachers	Being studied
OKLAHOMA	Scholarships in shortage areas	In shortage areas; coursework for full certification	Existing		Piloting
OREGON	Considering forgivable loans	Exams, LEA approval	Developing		Considering CL plan
PENNSYLVANIA	Forgivable loans and retraining funds in m/s	Intern program	Fully implemented in 1987		State funds for instructional improvement--some used by LEAs for CL or MP
RHODE ISLAND		Considering	Considering		
S. CAROLINA	Loans and scholarships; forgivable loans in m/s and rural areas	Exam, coursework for full certification	Existing	All teachers	Financial incentive program
SOUTH DAKOTA		Two years to meet full requirements	Existing		
TENNESSEE	Scholarships and forgivable loans to recruit & retrain in m/s		As part of CL plan		5-tier CL plan
TEXAS	Forgivable loans to recruit and retrain in shortage areas	Exams, internship		Beginning teachers	4-tier CL plan
UTAH	Scholarships		Being developed	All teachers	CL plan partially implemented
VERMONT	Forgivable loans in m/s	Experience, evaluation			

STATE	INCENTIVE Scholarship or loan	Alternative Certification Route	Induction program	Salary Increases	Career ladder/ merit pay
VIRGINIA	Forgivable loans in shortage areas	Secondary level: exam, internship	Existing	All teachers	Pay-for-performance plan
WASHINGTON	Forgivable loans in m/s		Existing		
WEST VIRGINIA	Scholarships in shortage areas	In shortage areas: exam, internship	Considering		Incentive policy being formulated
WISCONSIN			Proposed; 2 pilots		CL plan partly funded
WYOMING	Forgivable loans		Proposed		

Financial aid programs. Such programs tend to be one of four types: scholarships, loans, forgivable loans, and retraining funds (e.g., any of the preceding forms of aid, or tuition reimbursement). Scholarship programs exist to encourage college undergraduates to enter teacher training programs; often these scholarships are reserved for the most academically-able students, or for students entering teaching in shortage areas. Of the 12 states that offer teacher training scholarships, six have separate scholarships to encourage students to enter mathematics and science (or shortage area) teaching.

Student loans are also commonly used to encourage entry to teacher training programs. Forgivable loans are a particularly popular policy, as they encourage teacher candidates to obtain certification and enter teaching for at least a brief period of time. Twenty-eight states have forgivable loan programs; four have regular loan programs in addition to forgivable loan programs.

Forgivable loans come in a variety of forms, the most general of which involves the forgiving of a certain percentage (usually 20 percent) or amount (usually one year) of the loan for each year in which the recipient teaches within the state. Most state forgivable loan programs are only for shortage areas. Eleven states have forgivable loan programs targeted for mathematics and science teachers, and an additional ten states forgive loans given to teachers in "shortage areas". Three states forgive loans to teachers who work in districts that tend to have shortages: Alaska and South Carolina forgive loans of those who teach in rural districts, while Florida forgives loans of those who enter rural or urban districts.

Funding for retraining in mathematics and science may also be given to retrain practicing teachers. Eleven states offer some form of mathematics and science retraining funding, and an additional three states offer retraining funds for shortage areas.

Thirty-two states have alternative forms of certification, which function as a compromise between full certification and emergency certification. Emergency certification allows a teacher to enter the classroom without the normally requisite training. Usually, such certificates are temporary and are allowed only in shortage areas.

Alternative certification programs. Such programs typically require some minimal academic and/or subject-area standard (a subject-area major, minimum GPA, passing score on certification tests, etc.). The fulfillment of specified coursework for certification during the first few years of teaching is required; the specific requirements, however, vary widely from state to state. They generally include academic and/or testing requirements to receive the initial provisional certificate, and coursework and internship requirements in order to maintain the certificate and eventually receive a more permanent certificate.

A number of universities have launched nontraditional teacher preparation programs, defined here as academic programs to prepare college graduates for teaching who did not major in education or take the necessary courses for certification as undergraduates. These graduate level programs are designed to provide the pedagogical (and other) coursework necessary for college graduates to obtain full certification. Programs tend to be targeted toward recent baccalaureates, mid-career transfers, and retirees (Carey, Mittman, and Darling-Hammond, 1988).

Teacher training has traditionally not been a state responsibility; therefore, development of nontraditional teacher preparation programs have tended to be more of a local university/college initiative than a state initiative. Nonetheless, at least twelve states have collaborated with state higher education institutions to develop such programs. First, two states (Arizona and Connecticut) have developed special teacher training programs for recent college graduates with a baccalaureate degree in an appropriate subject area field.

A recent national survey of nontraditional teacher training programs (Carey, Mittman and Darling-Hammond, 1988) located 64 such programs nation-wide (including the twelve mentioned above). Many, but not all, of these programs restrict entry to those training in specified shortage areas. Most of the non-state programs are run through the education department of an institution of higher education, but funding sources for the programs are highly varied, with some receiving federal funds, some state funds, some corporate funds, and some funded mostly by tuition.

Recruitment/Retention Policies at the State Level. (See Table 1)

Salary Policies. State activity in the area of teacher salary increases is limited by the nature of educational financing. That is, most state aid to local districts is either general assistance or limited to categorical programs. While specific salaries are derived mostly at the local level, often through collective bargaining, increases in general student aid has an indirect effect on increased salaries. That is, increased uncommitted funds can be used to increase the salaries and benefits of teachers.

In spite of limitations on state policies vis-a-vis local policies and collective bargaining agreements, an increasing number of states have set statewide minimum starting salaries for teachers. Some have instituted a statewide salary schedule. Thirty states have statewide minimum salaries (these are voluntary in one state), and 19 states have a statewide salary schedule (Darling-Hammond & Berry, 1988). Some of the largest salary increases have been in southeastern states, where teachers have historically been the least well-paid: Texas, North Carolina, Oklahoma, Georgia, Alabama, and South Carolina have increased teacher salaries by over 20 percent between 1983 and 1985 (Darling-Hammond & Berry, 1988).

Policies related to the professional conditions of schools. Induction programs, while not as prolific as some initial recruitment incentives, can provide a calculable change in the teacher supply, particularly in large, urban school systems. Dade County, up until recent reform efforts, lost nearly 50 percent of their beginning teachers. Similar or worse stories have been described in other urban districts.

An increasing number of states have or are considering implementing some form of induction program. The usual such program is an intern or mentor teacher program, involving close cooperation between the new teacher and a carefully selected experienced teacher, who provides support and supervision. Sometimes the mentor evaluates the beginning teacher.

In some programs, the new teacher cannot be fully certified without passing an evaluation (or series of evaluations) during the initial year of teaching. In other programs, the evaluation(s) serves only as a means for the novice to recognize and address deficiencies. In 25 states and the District of Columbia, induction programs are in operation or being piloted. Six additional states are considering implementing some form of induction program. Note that an additional two states have mentor teacher programs as part of a career ladder program.

Pay-for-performance. The use of performance standards as a basis for compensation has been a popular activity during the 1980s (Darling-Hammond & Berry, 1988). These plans have taken many forms, including merit pay, incentive pay and salary incentive associated with career ladder or master/mentor teacher programs (or some combination of these). States that have an induction program typically have some sort of two-tiered career ladder, as mentor teachers are usually paid extra for their services in assisting the beginning teacher.

Programs that raise the financial rewards for those who demonstrate exemplary teaching enhance the quality of the teaching force by making teaching a more appealing long-term career choice for well-qualified teachers. Earlier attempts at instituting such plans, in the 1920 and 1950s, ran into many problems with implementation, particularly the implementation of teacher evaluation plans (see Darling-Hammond & Berry, 1988).

As of 1986, thirty-three states had at least considered some form of pay incentive or pay-for-performance plan; 21 of these have a plan in effect, five are piloting a plan, and the remaining seven have obtained initial funding, or are studying the issue. Most of these incentive pay plans are career ladder plans; "merit pay" appears to have become taboo, at least as so labelled.

Some states have already abandoned merit teacher programs, either due to financial constraints or court cases related to evaluation or selection procedures. Florida's career ladder/merit pay program was thrown out in state court and a subsequent career ladder program was enacted but never funded. Three states abandoned similar programs recommended by state task forces before they were implemented -- Kansas, Maine, and Mississippi. New Jersey eliminated a career ladder/merit pay program after initial experimentation. Plans for career ladder programs, or expansion of programs, have been frozen in six states. This pattern is part of the history of such efforts.

It is interesting to note also that many states with a mandated pay incentive plan allow districts to develop their own plans. This allows districts' some flexibility in designing pay programs that fit their resources and district priorities. Local plans also allow teachers to have more input into the design of these programs. A common problem with past programs was the lack of such input.

Analysis of Recruitment/Retention Policies: Salary Related Options

Approaches to increasing teacher pay. Historically, teacher salaries have followed trends in the teacher labor market. As mentioned previously, real pay for teachers rose in the 1960's, fell dramatically in the 1970's, and began to rise again in the mid 1980's. This increase in the 1980's resulted partly from 20 states who raised pay for beginning teachers (i.e., the minimum starting salary for teachers) and/or all teachers. An additional four states have recommended or are considering raising teacher pay. Four states raised teacher pay across the board and increased starting salaries. However, many states are seeking to develop alternative pay policies that are not simply across the board pay raises.

Performance and responsibility-based compensation programs. In many occupations, worker compensation is based in whole or in part on the adequacy of the workers' performance. Most typically, some combination of performance and job responsibilities determine compensation. Teaching does not operate in this manner.

Teaching has been described as a "flat" career. Typically, most teachers perform the same tasks and receive the same pay, with increments in compensation being related only to years of experience and educational background. Teachers have few opportunities to advance in the field of education without leaving the classroom. Increased compensation for additional duties occurs for those teachers who work additional hours as coaches or curriculum coordinators, but these are usually regarded as extra "jobs" rather than as increased responsibilities alloted as a reward for performance.

Teacher unions have historically been opposed to performance-based pay plans for a variety of reasons, difficulty in judging merit, a lack of commonly accepted definitions of outstanding performance, and the need to increase wages for all members.

Merit pay. Rigorous evaluations of the effectiveness of merit pay plans do not exist because merit pay plans do not survive long enough, or in a consistent enough form, to be meaningfully evaluated. There is some research examining the history of merit pay plans, the reasons for their discontinuance, and an analysis of those that survive by overcoming the problems that destroy other plans.

A summary of the economic literature on pay-for-performance compensation plans notes that for merit pay programs to work, the performance criteria on which salary increments are based must be validly operationalized (Murnane and Cohen, 1986). This is difficult for teaching, where the specific behaviors that constitute "good" teaching cannot be delineated. That is, effective teaching depends on circumstance and subject matter being taught. It cannot be characterized in terms of a universally applicable set of teaching behaviors or practices (Wise et al., 1984; Darling-Hammond and Hudson, 1986; Johnson, 1984).

As a result, teachers often view the evaluation procedures used in merit pay plans as invalid. Moreover, attempts to improve these evaluation plans (e.g., hiring more evaluators, increasing evaluator training) involve additional costs. Some analysis of the costs and effects of such plans have estimated that the instructional budgets of school systems would have to increase 10 to 15 percent to accommodate a fair evaluation system based strictly on performance --before any financial rewards were made (Wise, 1984).

When the behaviors that form the basis of the pay-for-performance criteria cannot be specified, the plan becomes compromised. Teachers' perceive that judgments are not valid or reliable. Worse, they do not understand how to improve their performance. This, in turn, leads to hostility, resentment, and lowered morale. Hostility and resentment are engendered both among teachers and between teachers and administrators. Such conditions are antithetical to schools' efforts to become more effective by developing school-level instructional teams, a goal of many reform efforts and a means to overcome professional isolation, one of the major problems of teaching careers (Murnane and Cohen, 1986).

But perhaps the most damaging evidence on the feasibility of developing an effective merit pay plan comes from Murnane and Cohen's (1986) analysis of merit pay plans with some longevity. These researchers found that the plans that survive tend to evolve into other forms of pay incentive plans that cannot legitimately be termed "merit pay" or "performance-based" plans. Similar findings occur in other occupations (Cresap et al., 1984). Pay-for-performance plans fail for the following reasons:

- The formal procedures used to evaluate teachers are of dubious validity as measures of teaching effectiveness --a problem that increases tension between teachers and administrators and teacher opposition to the plans.

For example, at least one relatively long-term career ladder program with an evaluation component (the Charlotte-Mecklenburg Plan) uses peer review, and has recently adjusted that process to make the evaluation criteria less quantitative and more qualitative (Cornet, 1988).

- The compensation levels set by merit pay plans do not usually match distinguishable differences in teaching effectiveness.

The recently enacted Fairfax County, VA merit pay plan has just been modified to reduce the plan's five compensation levels to only three levels.

- Finally, the exclusive focus on performance as the criterion for compensation in merit pay plans increases the importance of the performance evaluation process, which in turn exacerbates feelings of frustration with evaluation problems.

Career ladder plans. Unlike merit pay, career ladders are designed to reward teachers not only for outstanding teaching, but also for taking on more job responsibilities and participating in professional development. Thus, career ladders encourage teacher retention by increasing both the monetary and nonmonetary rewards of a teaching career. In so doing, these plans address both the inadequate pay issue, and the lack of career development/advancement.

The development of career paths for teachers is, in fact, a reform espoused by recent reports examining ways to improve teaching and teacher education (e.g., Holmes Report, 1986; Carnegie Forum, 1986). The American Federation of

Teachers has supported efforts to reward teachers, through status and financial differentials, for taking on additional professional responsibility.

In many career ladder plans, teaching is divided into three to five career levels. In other plans, usually called master or mentor teachers plans, there are only two levels--regular teachers and master/mentor teachers who are accorded more pay in exchange for (typically) supervising, assisting and evaluating first-year and other teachers. Career ladder plans are growing in popularity as an alternative pay incentive plan to merit pay plans. In some cases, merit pay plans have been replaced by career ladder plans (Murnane and Cohen, 1986; Darling-Hammond and Berry, 1988).

As of 1986, at least 18 states had enacted or were developing career ladder plans (Cornett, 1986). Evaluation is usually the least acceptable part of the plan to teachers, and the part that is most difficult to implement. For example, two of the earliest statewide career ladder plans (in Texas and Tennessee) are being revised to address problems in the evaluation systems and with administrative overload (Darling-Hammond and Berry, 1988). The evaluation component of the Tennessee plan was not supported by the state's teachers; 85 percent did not believe the career ladder evaluation system could work fairly or effectively (Olsen, 1987, in Darling-Hammond and Berry, 1988). Freiberg (1987, pp. 51-52) reports that teachers from these two states report the following concerns:

- the fairness of the evaluation system and of the criteria for moving up the career ladder; also the tendency of the evaluation to stifle creativity and the use of a wide range of teaching styles;
- additional teacher time required after school and in summer to reach the top rungs of the ladder;
- lack of teacher input into the development and implementation of the program;
- emphasis on external evaluation, rather than self-assessment, and the related emphasis on competition between teachers, rather than cooperation among teachers.

The newer programs tend to be locally developed which allows for more teacher input into program design and implementation. These programs acknowledge the need for more and more long-term funding, use multiple criteria for evaluation purposes, and require that teachers at even the top rungs spend at least half-time instructing students.

Many states are proceeding more cautiously, using pilot programs in local districts. As Darling-Hammond and Berry (1988, pp. 64-65) note: "The survival of career ladder programs will depend, in large part, on the ingenuity and perseverance of these test sites in developing credible and practicable solutions to the issues of evaluation."

Differential pay based on shortages: a study of five districts.

In recent years, faced with persistent shortages in some teaching specialty area, particularly science and mathematics, or in schools with poor working conditions, a small number of school districts have implemented various forms of differential pay in order to attract teachers into these specialties (five of which were studied for this report, see Grissmer, 1988). The structure of these incentives varies across district. Some are structured to aid recruiting new teachers only, while some help both recruiting and retaining present teachers. The incentives differ in their cost to districts and their effectiveness at eliminating shortages.

The simplest, although probably least cost effective, form of specialty-specific pay is to raise the salary of all teachers within a specialty. A second alternative is to raise the pay of incoming teachers only. This can be done in several ways. The most common form is offering a higher initial pay step, although a one-time bonus is also used.

A more restrictive variant is to offer higher pay only to certain new hires. For example, a "matching offer" program would first designate shortage specialties, but then allow discretion as to which new recruits received higher offers -- often restricted only to those who have higher offers in hand from other districts or industry.

Several districts, identified for this report, have tried some form of differential pay -- four in special teaching areas and one designed to alter the career paths of all teachers. The five districts are Houston, Boston, Hartford, Dade County, and Rochester (NY).

Houston's "Second Mile Plan" is an example of a local district incentive program. From 1982-83 to 1986-87, the Houston Independent School District implemented several pay incentive programs designed to increase teacher attendance and retention in critical shortage areas (both subject areas and school locales). End-of-the-year stipends were awarded to teachers who taught severely handicapped students (stipend of $750), regular special education ($525), bilingual education, mathematics, or science ($1500 each). To qualify a teacher had to pass the district's teacher assessment and meet attendance requirements. Teachers who met the attendance requirement of missing no more than five days were also given a bonus of $100 per day for each of the five allowed days that they did not miss (e.g., perfect attendance resulted in a bonus stipend of $500). Teachers were also given $200-$700 for professional development (postsecondary coursework), and $2000 stipends were given for teaching in a school designated as high priority.

The program's annual cost ranged from $7 million to $11 million over the four years of implementation. The state's (and district's) dwindling tax revenue because of oil price declines eventually led to curtailment of the program. In the last year of the program, stipends were cut and funding was eliminated altogether in 1987. Hatry and Griner (1984) report that an evaluation of Houston's plan after two years indicated improvements in teacher attendance and teacher turnover, and decreases in teacher vacancies.

Boston has a "matching" salary program whereby in designated teaching areas, new teachers may be placed higher on the pay scale than their experience would dictate. However, this is done only if needed to match existing salary offers from either other school districts or private industry. Areas currently designated as eligible for this program were bilingual education, special education, mathematics, all sciences and computer arts. The program also covered minority teachers. Approximately one-half of mathematics and science teachers were currently being hired under this program with enhanced pay. The level of enhanced pay often exceeded $5000 annually. The program grew from an older matching salary program in existence for over 10 years directed toward hiring vocational education teachers in certain specialties. No evaluation of the program has been done.

Hartford has had a program in existence for 10 years which allows higher placement on the pay scale for new teachers in shortage areas. Such areas are designated by the superintendent. Areas currently designated as shortage areas are bilingual education and special education. The program allows discretion on the part of the personnel director as to which individuals are made such offers. In general, Hartford and the state of Connecticut have had very few teaching shortages over the last 10 years, so the personnel director stated that he has used such offers only in a limited number of cases.

Dade County, Florida has several initiatives aimed at attracting teachers to specialty shortage areas. They have a $1000 first year bonus for new teachers in shortage areas. These areas include English, mathematics, all sciences, exceptional education and certain vocational education areas. The payment is given in the first year only, and no future salary is affected. This has been in operation for three years.

In addition, Dade County provides additional pay for "high priority schools" (school that are difficult to staff due to location or student population). Teachers are given annual salary increments of $500, $1000, $1500 and $2000 for their first, second, third and fourth years of teaching at a high priority school. After four years the increment is kept permanently at $2000. The state also provides one full tuition scholarship for each state high school for a student majoring in education. In addition $4000 scholarships are provided for students in their junior and senior year in college if they prepare for teaching in state shortage areas. Areas qualifying include mathematics, science, exceptional education, English and Foreign Language.

No evaluation has been done of these programs, but the personnel officer in Dade County stated that all programs are in their third year, and he thought them effective. He stated that mathematics and science shortages that were persistent over the last 5 years, while persisting, are no longer a major problem.

Rochester (NY) City School District's Career Teaching Plan, although not a differential pay plan, establishes four career levels for all teachers -- intern, resident, professional, and lead teacher. The program is designed to work hand-in-hand with other teaching profession and school reform efforts in

Rochester. For example, the career plan is designed to increase teacher decision-making in schools, improve the teacher induction program for new teachers, and make the teaching career one of --if not the-- most attractive positions in the school system.

"Lead" teachers will be paid nearly $70,000 to share their time between teaching responsibilities and other professional activities -- assisting beginning teacher interns, designing educational programs in inner city schools, developing curriculum, and so on. The program has just been initiated; however, it is included here to provide an example of a district effort to enhance teaching status, improve salaries over the professional life of a teacher, and provide professional opportunities for teachers without forcing them to leave the profession.

Although no formal evaluation has been done of such programs, we can nonetheless make some inferences regarding their cost-effectiveness based on their structure, knowledge of teacher recruiting and attrition patterns, and economic theory.

The programs that are likely to be efficient and effective in eliminating shortages need to affect both recruiting and early retention, as opposed to those directed toward career-committed teachers. Among the three options reviewed here --bonus, higher step, and permanent pay increase-- only the higher entry step program affects both recruiting and retention, and provides higher pay only during the critical early years. It thus avoids paying large amounts to teachers who are already career-committed. It would probably be the most cost-effective of the programs. If the higher step program is used selectively, its cost-effectiveness is enhanced even more.

Analysis of Recruitment/Retention Polices: Options Related to Improving the Professional Conditions of Schools

Overview. Emerging teacher shortages have prompted attention to those structural features of teaching which have made it relatively unattractive compared to alternative careers. The problems of teaching are well-known: long hours and wide-ranging responsibilities, low status, few opportunities for advancement or additional responsibility, and working conditions that other professionals would find unacceptable -- lack of materials and equipment, limited access to basic work tools such as typewriters and telephones, no personal office space, lack of time for preparation and planning, and so on.

These problems have contributed to recent difficulties in recruiting teachers, as opportunities in other fields have become relatively more attractive and, for mathematics and science teachers, much more available. A number of diagnoses of the problem by blue-ribbon task forces and commissions as well as scholars have concluded that further educational improvement in American schools will depend first and foremost on the caliber of the teaching force. And, the caliber of the teaching force will depend largely on the pursuit of reforms that professionalize the teaching occupation (Carnegie Forum, 1986; National Governors Association, 1986).

In addition to general occupational problems, teaching compares unfavorably with other professions. The problems of teaching as a profession are more subtle, but equally important. Low levels of investment in teacher preparation, induction, and ongoing professional development have slowed the professionalization of teaching by impeding the development of a knowledge base for teaching and its transmission to new entrants.

Since teachers are motivated primarily by their effectiveness with students (Rosenholtz and Smylie, 1984), conditions that undermine teacher efficacy (ranging from lack of knowledge to poor teaching conditions) contribute to disaffection and attrition. Limited teacher education reduces the teachers' arsenal of knowledge and skills with which to meet students' needs. Teacher isolation impairs the sharing of knowledge and problem-solving among teachers. A sink-or-swim approach to entry reduces the probability that new teachers will learn to be effective while increasing early attrition.

Bureaucratic procedures, often intended to compensate for lack of teacher knowledge, frequently constrain teachers in ways that hamper their effectiveness. These aspects of teaching, which currently prevent it from becoming a profession (and its members from being treated as full professionals) are the targets of new initiatives in many states intended to address teacher shortages and quality by improving the preparation of teachers and the professional conditions of teaching.

Professionalizing policies are those that seek to improve the supply of well-qualified teachers, enhance their preparation, and encourage the production and transmittal of teaching knowledge. They include strategies to improve the effective training, recruitment and retention of talented teachers as well as strategies to reduce teacher isolation, increase teachers' input into instructional decision making, and encourage collegial problem-solving.

Improved Preparation and Induction. Like others who enter teaching, mathematics and science teacher recruits explain their choice in terms of service motives and personal values, such as a desire to work with children, to contribute to society, and to foster learning (Darling-Hammond, Hudson, and Kirby, forthcoming). The primary reward of teaching is a sense that the teacher is contributing to the growth and development of his or her students. This sense of efficacy is crucial for teacher improvement (Darling-Hammond et al., 1983; Rosenholtz and Smylie, 1984), and it strongly affects student learning outcomes (Berman and McLaughlin, 1977; Armor et al., 1976; Brookover, 1977; Rutter et al., 1979).

Teacher attrition is related to those teaching conditions that influence teacher efficacy -- that is, the teacher's ability to do an effective job of teaching (Rosenholtz and Smylie, 1984). Those who are better prepared for the challenge of the classroom and those who are better supported in their initial months of teaching are more efficacious. They are less likely to become discouraged and join the large ranks of early leavers who comprise a third or more of beginning teachers.

New recruits to mathematics and science teaching affirm the importance of adequate preparation and early mentoring. Those who receive good preservice education and supportive supervision as beginners appear much more likely to feel efficacious and successful than those who enter through special routes that truncate preparation and early mentoring. Those who receive good preservice education and supportive supervision as beginners appear much more likely to feel efficacious and successful than those who enter through special routes that truncate preparation and fail to offer adequate induction (Darling-Hammond, Hudson, and Kirby, forthcoming).

Many states and districts are launching or considering induction or internship programs for beginning teachers. This is an important departure from the traditional sink-or-swim approach to beginning teaching for two equally important reasons: (1) because teaching knowledge is complex and requires judgment in its application, it cannot be fully acquired in a teacher education classroom; and (2) because a teaching profession is first and foremost committed to the welfare of students, inexperienced practitioners cannot be allowed to learn on the job without guidance. Sustained induction is necessary as well to stem the high attrition rates of new teachers and to provide equity to students, since inexperienced teachers are not randomly distributed across all types of schools and students.

Beginning teachers are typically placed in disproportionate numbers in the schools and classrooms serving less advantaged students. Schools with high turnover rates are those abandoned by more experienced teachers who seniority allows them to receive transfers to more desirable locations. They are also the schools which, by necessity, hire the most new teachers (Wise, Darling-Hammond, and Berry, 1987). Others have also affirmed this practice:

> New teachers are often given those students or courses with whom experienced teachers do not wish to deal. Instead of giving beginning teachers a nurturing environment in which to grow, we throw them into a war zone where both the demands and the mortality rate are excessively high (McLaughlin, et al, 1986).

Increased Collegiality and Authority. One of the greatest impediments to teachers' professional growth and skill development is teacher isolation (Rosenholtz and Smylie, 1984; Darling-Hammond et al., 1983; Lortie, 1975). As schools are traditionally structured, teachers spend most of their time physically isolated from colleagues, and there are often few organizational incentives for teacher interaction about specific problems of educational practice. Thus, teachers are unable to share their knowledge and teaching problems go unaddressed.

Effective schools, however, are characterized by collegial settings in which teachers are able to assist each other and to solve problems collectively. As in other professions where peer assistance and review are commonplace, these collegial school settings also enhance teacher satisfaction and efficacy along with student learning outcomes (Rosenholtz and Smylie, 1984; Walberg and Genova, 1982; Ashton et al, 1983). Experienced teachers profit from opportunities to assume new challenges and leadership roles, while less experienced teachers profit from the technical assistance provided by their veteran colleagues. Opportunities for leadership and professional recognition seem to enhance the retention of effective, experienced teachers (Rosenholtz and Smylie, 1984; Chapman and Hutcheson, 1982; Stark et al., 1980).

Current efforts to restructure schools so that they focus more productively on teaching and learning involve a variety of changes that increase time for collective teacher planning, preparation, and problem-solving as well as increasing the personal attention students can receive. These changes range from team teaching arrangements with joint planning time for teachers to core curriculum arrangements which reduce the absolute numbers of students each teacher must come to know. When schedules are under the control of teacher teams, many more productive strategies become possible.

The benefits of increased faculty involvement in decision making are confirmed by the effective schools literature, which indicates that participatory school management by teachers and principals produces both student learning gains and increased teacher satisfaction and retention (Mackenzie, 1983; Pratzner, 1984).

Resource allocations and professionalization. Professionalizing teaching suggests a reallocation of educational dollars as investments are made in "front line" human capital more than monitoring and inspection system. If teachers are more carefully prepared and selected, expenditures for management systems designed to control incompetence can be reduced. If investments are made in the front-end of the teaching career for induction support and pre-tenure evaluation, the costs of continually recruiting and hiring new entrants to replace the 30-50 percent who leave in the first few years will decline

The costs of band-aid approaches to staff development for those who have not learned to teach effectively will be reduced. Similarly the costs of remediating or seeking to dismiss poor teachers -- as well as compensating fo the effects of their poor teaching on children -- will decrease. The basic notion of professionalization is that strategic investment in teacher competence frees up resources for innovation and learning (Darling-Hammond, 1988).

WHAT NEEDS TO BE DONE?

The quality of the teaching force in science and mathematics is a primary concern of the National Science Foundation. The quality of that human resource pool is directly related to high quality teacher preparation programs, the recruitment and retention of science and mathematics teachers, and their continuing professional development. Problems related to these factors are particularly severe as they concern minority teachers and teachers in urban centers.

The design of the American educational system requires that improvements in the recruitment and retention of high quality mathematics and science teachers must take place at the local and state levels. The magnitude and nature of teaching quality problems dictate that a comprehensive and systemic approach needs to be taken. Again, this is particularly important in large urban districts where programs can be fragmented without specific efforts to coordinate them.

States need to consider the importance of salary and the professional conditions of schools and careers on science and mathematics teacher recruitment and retention. Scientists, educators, state and local education officials need to examine the effects of salaries and professional conditions on the quantity and quality of science and mathematics teachers. Through public reports and analyses of policy and programmatic options the Foundation is prepared to assist in this effort.

The Foundation, through its programs, is able to assist states and local districts in their teacher recruitment and retention efforts. While the Foundation is not in a position to provide operating support or salary resources, it provides support for efforts in teacher preparation, enhancement, recognition, and professionalization initiatives. These efforts are designed to enhance the teaching profession in the areas of science and mathematics.

In addition, the U.S. Department of Education, through the Eisenhower Mathematics and Science Education Act (PL100-297, formerly Title II of the Education for Economic Security Act) provides financial assistance to State educational agencies, local educational agencies, and institutions of higher education to strengthen the economic competitiveness and national security of the United States by improving the skills of teachers and the quality of instruction in mathematics and science.

Although there is limited information on the use of these funds, state program directors indicate that the primary focus is teacher training, including support for teachers and curriculum specialists to attend NSF-supported institutes and national and regional meetings of professional organizations (Marks 1986).

The NSF Directorate for Science and Engineering Education, through its Division of Teacher Preparation and Enhancement, currently supports activities that include, but are not limited to, the following:

- The development and evaluation of innovative undergraduate programs for the preparation of future teachers of science and/or mathematics in the elementary, middle/junior high, or high schools.
- The development and evaluation of courses, materials, or software that strengthen the preservice preparation of teachers by addressing areas of weakness in current programs relative to basic knowledge in science, mathematics and technology, and/or effective methods for teaching and learning those subjects.
- The development and evaluation of innovative experiences for preservice or beginning teachers that will improve their effectiveness as teachers and will facilitate their induction into the profession.
- The development and evaluation of recruitment and retention strategies for attracting and retaining talented students, particularly members of underrepresented populations, in teacher preparation programs.
- Research on effective strategies relative to the preservice preparation of teachers and their induction into the profession.
- The development and evaluation of programs designed to address new or emerging teacher certifications in science or mathematics.

Note: These programmatic efforts, in each case, include specific initiatives to explore and improve the successful participation of minorities and other underrepresented groups in science and engineering. The strong equity concerns of the Foundation make it imperative that specific and comprehensive efforts be focused on cities with large concentrations of minority students. The Directorate has taken specific steps to direct programmatic efforts at urban areas and in school systems with large proportions of minorities.

Improving Urban Science and Mathematics Education

The growing need for mathematics, science, and technology education, and the growing proportions of minority groups in our national demographics, make it urgent for the National Science Foundation to address the needs of urban schools where large numbers of minority students attend. Projects funded by the Foundation's teacher enhancement and materials development programs are already active in city schools. Future projects can tie together these activities in a more complete manner.

NSF will be responsive to comprehensive, systemic urban initiatives whenever improvement seems likely, and wherever there is a clear interest on the part of the school system to work with the science, mathematics, and related education communities. An appropriate comprehensive project might include groups of scientists and mathematicians working with education scholars to provide teachers with technical assistance in the design and development of school-based professional development and training efforts. Simultaneously, education scholars would collaborate with school-based faculty and staff in projects to improve professional conditions at the school, (e.g., new curriculum, cooperative learning, peer coaching, team teaching, special staffing, new standards and revised schedules). Assessment experts could work to assure that student assessment and district accountability programs support desired student learning. All of these components, under a collaborative umbrella, would constitute a promising systemic reform.

Any systemic improvement effort would include elements of professional development for teachers, substantial changes in the role, status and training of teachers, and significant evidence of improved system support. This might include such devices as specialized teaching and/or support staff in the science and mathematics areas, increased teacher preparation time, improved laboratories, and/or many other techniques that have been suggested by education observers. Some current NSF programs address one or more of these issues; however, systemic efforts will need simultaneous action on all fronts.

Ultimately, however, improvement in science and mathematics education must take place locally within schools. There is increasing agreement that the critical decisions regarding improvement in education programs must involve the people who are closest to the learners -- teachers and school-based administrators.

This is especially true in the case of the large urban systems, which also have the most severe problems. Their students tend to drop out early; avoid science, mathematics, and engineering; and are among those who are least successful in science and mathematics courses.

Successful systemic improvements should integrate science and mathematics improvement with broad reform efforts stimulated by local, state, and national leadership commissions involving educators, business leaders, and government officials. NSF has initiated some of these activities through its Science and Engineering Education programs. For example, NSF has supported the Mathematical Science Education Board and the American Association for the Advancement of Science efforts to define essential learning in science and mathematics. Teacher enhancement projects have increased teacher leadership capacities and the content knowledge of classroom teachers. And, materials development projects in elementary science are being pilot tested in hundreds of schools.

Future systemic efforts will be in a position to use what has been supported and tie the following discrete efforts together:

o redefine the learning outcomes essential for a K-12 science and mathematics education;

o experiment with alternative approaches to staffing science and mathematics teaching;

o increase teacher participation in designing the mathematics/science curriculum and selecting materials;

o improve the content knowledge and skills of teachers; (professional development)

- experiment with alternative teaching arrangements, organizational structures, and decision making procedures.

State Science and Mathematics Education Improvement

State governments have the principle responsibility for public education. Governors, legislators, and chief state school officers, working together with scientists, mathematicians, and educators, are in a strategic position to develop and implement a comprehensive set of science and mathematics education improvements. States will need to assess policies, regulatory practices, rewards, barriers, and incentives as they relate to science and mathematics teaching and learning.

Comprehensive state initiated policies and program incentives for the improvement of school-based K-12 science and mathematics education are needed. Such programs should be designed to make teaching an attractive career for individuals who have strong backgrounds in science and mathematics. Such programs, consistent with or in support of local initiatives, should include efforts to:

- examine and initiate appropriate state policies and practices related to the recruitment and retention of science and mathematics teachers.
- improve the preparation and induction of new science and mathematics teachers and to reduce needless barriers to entry into the profession by individuals with strong backgrounds in science and mathematics.
- experiment with new types of policies which provide incentives for school districts to support school-based improvements which enhance the professional conditions for teachers and their careers.
- review state school regulations that impede the implementation of sound curricular and teaching practices (e.g., student testing or assessment programs in science and mathematics so that they are consistent with desired learning goals for students).
- support staff development and technical assistance to local schools.
- devise incentives which promote local school decision making on the part of the teachers and assure that those decisions are as fully informed as possible with regard to sound content and teaching knowledge in science and mathematics.

REFERENCES

AACTE, Teacher Education in the States: A 50-State Survey of Legislative and Administrative Actions, Washington, D.C., 1987.

Aldridge, B.G., What's being taught and who's teaching it, Audrey B. Champagne and Leslie E. Hornig (Eds.). The Science Curriculum. Washington, D.C.: American Association for the Advancement of Science, 1987.

Armor, D., Conry-Oseguera, P., Cox M., King, N., McDonnell, L., Pascal, A., Pauly, E., & Zellman, G., Analysis of the School Preferred Reading Program in Selected Los Angeles Minority Schools. Santa Monica, Ca.: RAND Corporation, 1976.

Ashton, P.T., R.B. Webb, and N. Doda, A Study of Teachers' Sense of Efficacy: Final Report, The University of Florida Foundations of Education, Gainesville, Florida, 1983.

Association for School, College, and University Staffing (ASCUS), Teacher Supply/Demand 1986, Madison, Wisconsin, 1986.

Berman, P., & McLaughlin, M.W., Federal Programs Supporting Education Change. Vol. 7: Factors affecting implementation and continuation. Santa Monica, Ca.: The RAND Corporation, 1977.

Bredeson, P.V., Fruth, M.J., & Kasten, K.L., Organizational Incentives and Secondary School Teaching. Journal of Research and Development in Education, 1983, 16, 52-56.

Brookover, W., Schools Can Make a Difference. East Lansing: College of Urban Development, Michigan State University, 1977.

Calhoun, F.S., and N.J. Protheroe., Merit Pay Plans for Teachers: Status and Descriptions, Educational Research Service, Arlington, Virginia, 1983.

Carey, N.B., B.S. Mittman, and L. Darling-Hammond, Recruiting Mathematics and Science Teachers Through Non-Traditional Programs: A Survey, The RAND Corporation, N-2736-FF/CSTP, 1988.

Carnegie Forum on Education and the Economy (1986)., A Nation Prepared: Teachers for the 21st Century. New York: Carnegie Corporation.

Carnegie Forum on Education and the Economy, A Nation Prepared: Teachers for the 21st Century, Washington, D.C., 1986.

Chapman, D.W., and S.M. Hutcheson, Attrition From Teaching Careers: A Discriminant Analysis, American Education Research Journal, Vol. 19, 1982, pp. 93-105.

Cohn, M.M., R.B. Kottkamp, G.N. McCloskey, and E.F. Provenzo, Teachers' Perspectives on the Problems of Their Profession: Implications for Policymakers and Practitioners, paper prepared for the Office of Educational Research and Improvement, U.S. Department of Education, no date.

Coley, R.J., and M.E. Thorpe, Responding to the Crisis in Math and Science Teaching: Four Initiatives, Educational Testing Service, Princeton, New Jersey, 1985.

Cornett, L., Serious Shortages of Science and Mathematics Teachers: What SREB States are Doing, Southern Regional Education Board, Atlanta, Georgia, 1986.

Cornett, L., Teacher Incentives: The Outsiders' View, Southern Regional Education Board, Atlanta, Georgia, 1988.

Cresap, McCormick, and Paget, Teacher Incentives: A Tool for Effective Management, National Association of Secondary School Principals, National Association of Elementary School Principals, American Association of School Administrators, Reston, Virginia, 1984.

Darling-Hammond, L., Beyond the Commission Reports: The Coming Crisis in Teaching, The RAND Corporation, R-3177-RC, 1984.

Darling-Hammond, L., and B. Berry, The Evolution of Teacher Policy, The RAND Corporation, 1988.

Darling-Hammond, L., Hudson, L., Kirby, S.N. Nontraditional programs to Prepare Mathematics and Science Teachers. Santa Monica: The RAND Corporation, R-3661 (forthcoming).

Darling-Hammond, L., and L. Hudson, Precollege Science and Mathematics Teachers: Supply, Demand, and Quality, paper prepared for the National Science Foundation, Washington, D.C., 1987.

Darling-Hammond, L., L. Hudson, and S.N. Kirby, Recruiting Mathematics and Science Teachers Through Non-Traditional Programs: Perspectives of Participants and Graduates, The RAND Corporation, forthcoming.

Darling-Hammond, L., A.E. Wise, and S.R. Pease, Teacher Evaluation in the Organizational Context: A Review of the Literature, Review of Educational Research, Vol. 53, No. 3, 1983, pp. 285-328.

Fox, S.M., and T.J. Singletary, Deductions About Supportive Induction, Journal of Teacher Education, Vol. 37, No. 1, 1986, pp. 12-15.

Freiberg, H.J., Career Ladders: Messages Gleaned from Experience, Journal of Teacher Education, Vol. 38, No. 4, 1987, pp. 49-56.

Freiberg, H.J., Master Teacher Programs: Lessons From the Past, Educational Leadership, Vol. 42, No. 4, 1985, pp. 16-21.

Gaede, O.F., Reality Shock: A Problem Among First-Year Teachers, The Clearing House, Vol. 51, No. 9, 1978, pp. 405-409.

Gosman, E., Quality in Teacher Education: A Crisis Revisited, The Western Interstate Commission for Higher Education, Boulder, Colorado, 1985.

Grissmer, D.W., Teacher salary case studies, data collected for an unpublished report for the National Science Foundation, Washington, D.C. 1988.

Grissmer, D.W., and S.N. Kirby, Teacher Attrition: The Uphill Climb to Staff the Nation's Schools, The RAND Corporation, R-3512-CSTP, 1987.

Haggstrom, G., L. Darling-Hammond, and D.W. Grissmer, Assessing Teacher Supply and Demand, The RAND Corporation, R-3633-ED/CSTP, 1988.

Hatry, H.P., and J.M. Greiner, Issues in Teacher Incentive Plans, The Urban Institute, Washington, D.C., 1984.

Hoffman, J.V., S.A. Edwards, S. O'Neal, et al., A Study of State-Mandated Beginning Teacher Programs," Journal of Teacher Education, Vol. 37, No. 1, 1986, pp. 16-21.

The Holmes Group, Tomorrow's Teachers. East Lansing, MI. 1986.

Howe, T.G., and J.A. Gerlovich, National Study of the Estimated Supply and Demand of Secondary Science and Mathematics Teachers, 1980-1982, Iowa State University, Ames, Iowa, 1982.

Hudson, L., Issues in Science Teacher Supply and Demand: Data Needs and Policy Acts, in Audrey Champagne (ed.) Science Teaching: Making the System Work, American Association for the Advancement of Science, Washington, D.C., 1988. pp. 41-60.

Hudson, L., S.N. Kirby, N.B. Carey, et al., Recruiting Mathematics and Science Teachers Through Nontraditional Programs: Case Studies, The RAND Corporation, N-2768-FF/CSTP, 1988.

Huffman, G., and S. Leak, Beginning Teachers' Perceptions of Mentors, Journal of Teacher Education, Vol. 37, No. 1, 1986, pp. 22-25.

Huling-Austin, L., What Can and Cannot Reasonably be Expected From Teacher Induction Programs, Journal of Teacher Education, Vol. 37, No. 1, 1986, pp. 2-5.

Johnson, S.M., Merit Pay for Teachers: A Poor Prescription for Reform, Harvad Educational Review, Vol. 54, No. 2, 1984, pp. 175-185.

Jordon, K.F., and N.B. Borkow, Merit Pay for Elementary and Secondary School Teachers: Background Discussion and Analysis of Issues, Congressional Research Service, #83-541S, 1983.

Kershaw, J.A., and R.N. McKean, Teacher Shortages and Salary Schedules, McGraw-Hill, New York, 1962.

Levin, H.M., Solving the Shortage of Mathematics and Science Teachers, Educational Evaluation and Policy Analysis, Vol. 7, No. 4, 1985, pp. 371-382.

Litt, M.D., and Turk, D.C., Stress dissatisfaction, and intention to leave teaching in experienced public high school teachers. Paper annual meeting of the American Educational Research Association, Montreal, April, 1983.

Little, J.W., Norms of Collegiality and Experimentation: Workplace Conditions of School Success, American Educational Research Journal, Vol. 19, No. 3, 1982, pp. 325-340.

Lortie, D.C. Schoolteacher: A Sociological Study. Chicago: University of Chicago Press, 1975.

Marks, E.L., Title II of the Education for Economic Security Act: An Analysis of First-Year Operations, report prepared for the U.S. Department of Education, Policy Studies Associates, Washington, D.C., October 1986.

MacKenzie, D.E., Research for School Improvement: An Appraisal of Some Recent Trends. Educational Researcher, 1983, 12, 5-17.

McLaughlin, M.W. (1986). Why Teachers Won't Teach. Phi Delta Kappan, 67, 420-426.

Metropolitan Life Insurance Company, Metropolitan Life Survey of Former Teachers in America, Louis Harris and Associates, New York, 1987.

Meyer, H.H., The Pay-for-Performance Dilemma, Organizational Dynamics, Vol. 3, No. 3, 1975, pp. 39-50.

Mikalachki, A., There is No Merit in Merit Pay, The Business Quarterly, Spring 1976.

Murnane, R.J., and D.K. Cohen, Merit Pay and the Evaluation Problem: Why Most Merit Pay Plans Fail and a Few Survive, Harvard Educational Review, Vol. 56, No. 1, 1986, pp. 1-17.

Murnane, R.J., and R.J. Olsen, How Long Teachers Stay in Teaching Depends on Salaries and Opportunity Costs. Unpublished paper, October, 1987.

Murnane, R.J., and R.J. Olsen, The Effects of Salaries and Opportunity Costs on Length of Stay in Teaching, Evidence from North Carolina. Unpublished paper, September, 1988.

Murnane, R.J., J.D. Singer, and J.B. Willett, The Career Paths of Teachers, Educational Research, August-September, 1988, pp.22-30.

National Center for Education Statistics, The Digest of Education Statistics, 1987, U.S. Department of Education, 1987.

National Commission on Excellence in Education, A Nation at Risk, U.S. Government Printing Office, Washington, D.C., 1983.

National Education Association, Status of the American Public School Teacher 1985-86, Washington, D.C., 1987.

National Governors' Association, Time for Results: The Governors' 1991 Report on Education, National Governors' Association - Center for Policy Research, Washington, D.C., August 1986.

National Science Board, Educating Americans for the 21st Century, National Science Foundation, Washington, D.C., 1983.

National Science Board, Science and Engineering Indicators - 1987, The National Science Board, Washington, D.C., 1987.

Olsen, L., Performance Pay: New Pond for an Old Debate, Education Week, March 12, 1987. pp. 1 and 18-20

Peterson, P.E., On Economic and Policy Trends and Proposals, in A.B. Champagne and L.E. Horning (eds.), This Year in School Science 1985: Science Teaching, American Association for the Advancement of Science, Washington, D.C., 1986.

Pratzner, F.C. Quality of School Life: Foundations for Improvement. Educational Researcher, 1984, 13(3), 20-25.

Rosenholtz, S.J., and M.A. Smylie, Teacher Compensation and Career Ladders: Policy Implications from Research, paper commissioned by the Tennessee General Assembly's Select Committee on Education, 1984.

Rutter, M., Maughan, B., Mortimore, P. OUston, J., and Smith, A., Fifteen Thousand Hours: Secondary Schools and Their Effects on Children. Cambridge, Mass., 1979.

Sedlak, M., and S. Schlossman, Who Will Teach? Historical Perspectives on the Changing Appeal of Teaching as a Profession, The RAND Corporation, R-3472-CSTP, 1986.

Shymansky, J.A., and B.G. Aldridge, The Teacher Crisis in Secondary School Science and Mathematics, Educational Leadership, November 1982, pp. 61-62.

Spero, I.K., The Use of Financial Aid to Attract Prospective Teachers: A Survey of State Efforts, The College Entrance Examination Board, New York, 1986.

Stark, J.S. Austin, A.E., Lowther, M.A., Chapman, D.W., and Hutcheson, S.M., Teacher Certificate Recipients at the University of Michigan, 1946 through 1976; A 1980 Follow-Up Study. Ann Arbor, The University of Michigan, School of Education, 1980.

Stoddart, T., Forms of Teacher Preparation: Traditional and Alternate Routes, unpublished paper, Michigan State University, no date.

Varah, L.J., W.S. Theune, and L. Parker, Beginning Teachers: Sink or Swim? Journal of Teacher Education, Vol. 37, No. 1, 1986, pp. 30-34.

Veenman, S., Perceived Problems of Beginning Teachers, Review of Educational Research, Vol. 54, No. 2, 1984, pp. 143-178.

Walberg, H.J., & Genova, W.J., Staff, School, and Workshop Influences on Knowledge Use in Educational Improvement Efforts, Journal of Educational Research, 1982, 76, 67-80.

White, D.S., Can Merit Pay Work in Education? American Educator, Vol. 7, No. 4, 1983, pp. 8-11, 42.

Winstanley, N.B., Are Merit Increases Really Effective? Personnel Administrator, April 1982.

Wise, A.E., Darling Hammond, L., McLaughlin, M., and Bernstein, H., Teacher Evaluation: A Study of Effective Practices. Santa Monica, CA, The Rand Corporatoin, 1984.

Wise, A.E., L. Darling-Hammond, and B. Berry, Effective Teacher Selection: From Recruitment to Retention, The RAND Corporation, R-3462-NIE/CSTP, 1987.

Zumwalt, K.K, E. Saxl, E. Cohen, et al., What are the Factors Which Enable Some Teachers to Maintain Positive Attitudes About Their Jobs? Teachers College, Columbia University, New York, 1982.

APPENDIX V

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

OFFICE OF THE
DIRECTOR

APR 20 1989

April 3, 1989

Honorable Doug Walgren
Chairman, Subcommittee on Science,
  Research and Technology
Committee on Science, Space
  and Technology
House of Representatives
Washington, DC 20515

Dear Mr. Walgren:

I am pleased to submit this report on the structure of a "College/University Innovation Research" program. This report is requested in Section 114 of the 1989 National Science Foundation Authorization Act.

The report addresses the design of a program to assist members of the academic community in the pursuit of high quality research leading to potential commercialization, with emphasis on regional economic development. The program design is patterned on the current Small Business Innovation Research program. Implementation could come from any Federal agency, and would be most appropriate for a "mission agency."

I trust the report will help you in assessing the potential for regional economic development based upon university/business interaction. Moreover, I hope that the report will serve as a stimulus for your comments on the program's design and its implementation.

Sincerely,

Erich Bloch
Director

Enclosure: A Report: College/University Innovation Research

cc: Honorable Sherwood Boehlert

A REPORT: COLLEGE AND UNIVERSITY INNOVATION RESEARCH

I. INTRODUCTION

Section 114 of the National Science Foundation Authorization Act of 1989 requires the preparation and submission of a report on how to assist members of the academic community to pursue high quality research of economic potential. Such research would be conducted at a wide range of colleges and universities, including smaller institutions which do not traditionally receive Federal research funds. The Act specifies that the report shall:

* describe the procedures, terms, and conditions necessary for the establishment of a program patterned after the Small Business Innovation Research Program to assist college and university faculty to pursue research of economic potential;

* analyze the feasibility of establishing funding recoupment mechanisms to offset the cost of such assistance; and

* state whether such a program is appropriate and feasible and, if so, the steps which shall be taken to establish and carry out such a program.

These three issues are addressed in the following sections of this report.

II. PROGRAM DESCRIPTION

Many academic researchers have expressed interest in a program to convert their research results into usable technology. Ten years of successful Federal experience with the Small Business Innovation Research (SBIR) program, which also strives for technology transfer and regional economic devlopment, suggests that a CUIR program patterned on the SBIR program has high potential for success.

Program Design

The program design for CUIR follows the SBIR pattern. It starts with a program solicitation calling for Phase I proposals for work at a college or university, and follows through with a Phase II research award to competitively selected Phase I awardees. Phase II research would be carried out in both the university and the private sector. Phase III comprises the private-sector sponsored development and commercialization effort. A more detailed description of the proposed program follows.

Phase I (Feasibility): Performance Period and Funding

Because Phase I addresses only the feasibility of a research concept, the SBIR program experience indicates that a short research term is desirable. The underlying logic is that a successful first phase serves to validate a research concept. It is this phase which furnishes the data, in minimum time and cost, that determine whether a major applied research thrust should be initiated. Moreover, because this report considers a five year pilot study, long Phase I projects would hamper the evaluation of the program's merits. Thus, a six-month term for Phase I seems appropriate. The timing of Phase I program awards would be made so as to permit much of the project work to be carried out during the summer when university researchers can devote more attention to it.

With regard to the level of Phase I research support, it appears that similar funding should be required in academia for accomplishing the Phase I "validation" objective (i.e., showing the potential of the proposed research) as is required by the small business community under the SBIR program. Thus a $50K, six-month period Phase I is recommended. Phase I research objectives should thus be similar to those for SBIR, with one addition: during the Phase I period, the academic researcher must select a private sector "partner" with whom to collaborate in later stages of the project.

This partner must participate in the Phase II research to enhance commercialization potential of the project. This "partnership" is an essential component of the knowledge and technology transfer process, as well as of economic development resulting from such university/business coupling. This partnership concept constitutes a major departure of the CUIR approach from the SBIR model.

Phase II (Research Performance and Funding)

The Phase II program should be a two-year research effort at about the $250-300K level. The objectives of this phase are the completion of the necessary research, the involvement of a private sector research organization and, where appropriate, the training of students. If the program is to serve a technology transfer function to convert university research into technology, then there must be significant private sector research participation in this phase to insure the commercial direction. Since the program strives for conversion of research into commercially viable technology, some research during this stage is likely to be "proprietary" in nature. This raises the question of the impact of CUIR research on other research in the university laboratory. To avoid the conduct of proprietary research on campus, it is recommended that Phase II awards be made to the small business firm, with research performed jointly in both the small business and university laboratory: non-proprietary portions may be carried out by the college/university partners in their laboratories. This arrangement will insure both improved technology transfer and, at the same time, protection of those proprietary aspects of the research. Therefore, jointly prepared Phase II proposals would be submitted by the private sector partner and would contain the commitment to proceed to Phase III, provided the research is successful and a potential market for the technology exists.

Phase III (Developmental Performance and Funding)

A developmental Phase III is provided by private-sector funding to commercialize the technology. The performance period cannot be clearly defined and depends upon the technology. Funding might come, as in the case of SBIR, from large industrial firms, Federal technical agencies, venture capital firms, joint ventures, R&D limited partnerships, advance purchase orders, State development agencies, and other sources, including the small firm itself, provided that its assets are sufficient.

Consideration for "Less Funded Research Institutions" (LFRI)

Review of Federal research awards indicates that among those 185 institutions normally considered as "research universities," approximately 80% of the support went to the top 55 institutions. The Foundation's experience with the SBIR program shows similar trends. In this instance eighteen of the fifty states received almost 87% of the awards. Consequently, there appears to be justification for a special consideration for awards to investigators in LFRI's and in states where technologically based economic growth has not occurred, provided the research was judged meritorious. In many instances, the LFRI's may not have sufficient facilities or instrumentation to carry out the work as efficiently. Therefore, if the objectives of assuring participation of lesser research institutions, minority institutions, and intitutions located where regional devlopment by promoting economic growth through technology are to be met, some special criteria must be included in the evaluation process that take account of the particular circumstances of these participants.

The Foundation already has special programs of this type; for example, the EPSCoR program. Based on this experience, regional economic development potential must be accorded major importance in the proposal review and evaluation process. Proposal evaluation criteria can be developed which, while continuing to insure high quality research, emphasize the innovative nature of the project and the relative local economic benefits of high technology business development. Grantee selection would emphasize technical merit in conjunction with commercialization potential. The proposal screening and review process would follow the general procedures used in the SBIR program, except that industrially based reviewers would be used extensively to screen for commercial value.

Role of Small Business

While it can be argued that private sector participation in Phases II and III should be open to all firms, there are arguments for restricting direct participation in CUIR to small businesses as research partners. Most large firms are already well coupled to the university research community and have other avenues for cooperation. It would be counterproductive, for example, if large firms were to substitute CUIR program funds for their ongoing university research commitments. Additionally, some of the most effective technology transfer paths have been between university research and small high-technology firms. Larger firms often enter the process for technology licensing, distribution, or even acquisition, when market pressures overtake technology development. In addition, the small business path offers the university researcher the opportunity to participate in the further development of a small firm. The partnership portion of the program should be limited to small business participation, at least during the pilot stage of the program.

III. RECOUPMENT

The concept underlying the "recoupment" of research expenditures is that profits stemming from "successful" projects constitute input to a fund which supports new projects. In theory, this would make the program self-sustaining. This provision entails problems in its administration for the Government and the university, and may tend to limit subsequent private sector capital interest in the program. The recoupment concept was considered when the Federal patent procedures for small businesses and nonprofit institutions were revised in 1979. Recoupment was dropped from the legislation at that time because of anticipated implementation difficulties. Implementation of recoupment is difficult because it requires specific definitions of project success or failure, as well as the terms of repayment. These questions are discussed briefly in the following paragraphs.

The administrative problems relate to the filing of patents by the university or the small business partner, and the subsequent ownership of patents or rights by these parties, should these become the basis for implementing recoupment. In this regard, it is important to establish levels of license fees or royalties, and how these are to be applied to recoupment. Another concern relates to capital investment potential. One of the major anticipated benefits of the program is enhanced economic growth on a regional basis. This requires the influx of private sector capital in the later stages of the program. Private investment sources might view a recoupment provision as an "encumbrance" on the technology. Thus, recoupment might well inhibit the influx of private capital for Phase III and stifle the important objectives of regional economic development and technology transfer.

Additionally, the requirement of "recoupment" or "forgivable loans" raises several important questions of definition in its implementation. The first is: who pays back the original "loan," the academic institution or the private sector business that eventually commercializes the technology? Second, what is the basis for the recoupment? Is the basis to be a royalty on units produced, on sales volume, or on the profits of the commercializing firm? If the basis for recoupment is to be a university-owned patent obtained as a consequence of the grant, academic institutions may not be too keen on accumulating present "debt" in the hopes of a risky payoff later. A third and more difficult issue is the question of and criteria for "success." How is success to be measured and how is ownership to be apportioned? Finally, "forgiveness" criteria must also be developed to take care of the projects which are not successful. Thus, the recoupment requirement envisioned in the legislative proposal raises many questions of a legal and economic nature which might well jeopardize the benefits of the program.

There are possible organizational mechanisms which could be used to overcome the above-listed problems. Among these are limited R&D partnerships in which the supporting agency, the academic institution, venture capital, and the private sector small business become partners. Most Federal agencies and academic institutions lack experience in the role of putting together such an organizational structure. Indeed, some academic institutions may find such a role inappropriate for them as non-profit educational entities. Thus, implementing such an approach could become a major administrative problem.

Since the program seeks to stimulate early innovative development followed by larger firm interest or investment, the ultimate aim is to create investment opportunity, stimulate new product sales, and obtain profits and growth. If the program is successful, it should stimulate and provide incentives for growth of the GNP. Since revenues from federal taxes amount to about twenty cents of every GNP dollar, this type of eventual payback represents recoupment in a very real, albeit indirect sense.

Direct recoupment based upon license fees, or other complex contractual processes, provide investment disincentives and inhibit economic development, thereby preventing accomplishment of program objectives. Patent and license questions between universities and the private sector remain their mutual responsibility. The sponsoring agency should not be placed in the position of becoming the focus of recovering costs of successful government-funded research.

IV. PROGRAM FEASIBILITY

Because of a decade of Federal experience of with the SBIR program, it appears that a program structured as outlined above could be implemented, possibly on an experimental basis. If the program were initiated, an evaluation component should be included in the program at the outset. For illustration, an example of the cost of a five-year pilot CUIR program is given in an appendix to this report.

Program Administration Needs

The administration and management costs are estimated at 8% of the program costs. This figure provides for program staff, administrative personnel costs, and proposal evaluation expenses.

Evaluation

An evaluation component should be incorporated in the program from the beginning, and that funding for this should be included in any new program budget. At the outset of the program, it is suggested that "baseline data" on the technology transfer of research, and the entrepreneurial attributes of the research faculty be obtained to the extent possible. Budgeting 1% of the program funds would provide significant evaluation data.

Program Implementation

As envisaged, the program would follow much the same process as the SBIR program, with a solicitation issued annually, allowing two months proposal response. The topic areas in the solicitation would be similar to,perhaps even identical with, the SBIR topics. With regard to eligibility for submitting a proposal, all faculty members at research institutions would be encouraged to participate.

While implementation of a CUIR program at the Foundation is feasible, questions of purpose and priorities arise. Budget constraints dictate the ordering of the Foundation's objectives and assigning prioities to them. The primary thrusts of the Foundation's programs are the support of leading-edge research at universities, with the consequent increase of the knowledge base, human resources development,and the support of education in science and engineering. Thus, the ranking of a CUIR program among the Foundation's priorities lies below those inititiatives for supporting scientific and engineering research, with adequate provisions for the enhancement of science education. While the effort under Phase I of a CUIR program is an extension of the Foundation's primary research thrusts, the Phase II efforts are more applied in their nature. Beneficiaries of these Phase II efforts are the Federal mission agencies and the private sector.

Therefore, one approach to achieving the technology transfer and economic growth objectives of a CUIR program is to turn the support of Phase II projects over to the mission agencies or the private sector.

V. SUMMARY OF RECOMMENDATIONS AND CONCLUSIONS

The Foundation believes that the outlined CUIR program can be successfully implemented on an experimental basis. The following specific elements characterize the recommended experimental program:

- the CUIR program solicitation would parallel the SBIR solicitation topics,
- all faculty at research institutions would be encouraged to participate,
- Phase I feasibility project would be for six months with a maximum of $50K,
- Phase II research program would be for two years at $250-300K, performed jointly by a university/industry partnership,
- industrial partnerships would be restricted to small business with Phase III follow-on funding commitment required,
- recoupment would be excluded because of implementation problems, and
- an evaluation component would be included at the outset.

Implementation of this program at the Foundation would require specific additional budget authority to cover the estimated program and staff costs. Evaluation is key to the assessment of whether the program works in expanding high-technology economic growth, and in promoting the transfer of knowledge from the university research base to industry.

However, there are some concerns surrounding the implementation of the CUIR program, including:

- The impact of the CUIR research on other research in university laboratories if proprietary research is involved.
- If Phase II awards under a CUIR program are made to small businesses to assure retention of proprietary data and to promote commercial potential, there is then little difference between the SBIR program and the CUIR program outlined, except for the ownership of any patents resulting from university initiation of the project. While colleges or universities cannot be awardees under the SBIR program,

the SBIR statute does not restrict their participation. Although the Small Business Administration policy restricts tenured faculty from serving as principal investigators because of their primary university employment, roughly fifty percent of the Foundation's SBIR grants presently have some college and university participation.

* There is little chance that CUIR could become self-sustaining. Thus, implementation of this program could come at the expense of higher priority research efforts.

* Because mission agencies would tend to reap greater benefits from the products developed, these agencies would be more appropriate for the program's implementation.

APPENDIX

ILLUSTRATIVE EXAMPLE OF PILOT PROGRAM COSTS

One of the major objectives of the pilot CUIR program is to determine whether stimulating the academic research community to interact with small business can reduce the time lag between investment in academic research and the first introduction of a commercial product. The average time lag for this process has been estimated by several researchers to be seven years. The success of a pilot CUIR program in addressing this objective depends to a large extent on the academic community's response to the program solicitation. This response, in turn, governs the cost of the pilot program.

Estimated Program Costs

It is difficult to estimate the response of the university research community to a CUIR program. However, it would not be unusual for a new program to stimulate the receipt of 1,000 proposals. Using a 10:1 ratio of proposals to awards for Phase I would result in about 100 awards (each at $50K) during the first year. This would require a first-year budget of approximately $5 million. In subsequent years, additional costs beyond the annual Phase I budget of $5 million would be incurred. These costs would result from the annual award of approximately 40 Phase II projects at $250-300K, or about $12 million. This would bring annual budgets in these out-years to about $17 million. In the sixth and final year of a five-year pilot effort, another 40 Phase II projects, selected from among the fifth year Phase I awards, would require a budget of about $12 million. Thus, the complete pilot effort would require total program funds of $85 million. Table 1 summarizes estimated cost elements by year.

Table 1 Summary of Estimated Costs

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Program Cost	$5.0M	$17M	$17M	$17M	$17M	$12M
Administration and Overhead Cost*	$400K	$1.3M	$1.3M	$1.3M	$1.3M	$1.0M

* Administration and Overhead expenses were estimated at 8% Of the program costs and include staff, proposal evaluation and processing, as well as program evaluation.

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NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

OFFICE OF THE
DIRECTOR

November 29, 1988

Honorable Robert A. Roe
Chairman
Committee on Science, Space and Technology
U. S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

As the Committee requested in its report accompanying the National Science Foundation Authorization Act for Fiscal Years 1989 and 1990 (H.R. 4418), I am pleased to enclose an FY 1988 list of awards for research involving acid rain.

Over the past three years research related to acid rain has increased steadily from sixty active awards in FY 1986, to sixty-three in FY 1987 and sixty-eight in FY 1988. Funding levels ranged from $1.49 million in FY 1986, to $2.30 million in FY 1987 and $1.97 million in FY 1988.

There is strong interest in this research area, as evidenced by the increase in number of awards. The decrease in dollars between FY 1987 and FY 1988 derives from awards initiating large-scale experiments on the nitrogen cycle. After large start-up investments in FY 1987, lower levels of funding are providing the support necessary to continue these experiments in FY 1988.

We will continue to monitor awards for fundamental research in this environmentally and economically important area, and will be happy to supply you with award lists in future fiscal years.

Sincerely,

Erich Bloch
Director

Enclosure

cc: Honorable Manuel Lujan, Jr. w/Enclosure

NATIONAL SCIENCE FOUNDATION

Division of Atmospheric Sciences

Acid-Rain Related Awards in FY 1988 (including references to projects ongoing in FY 1988 funded in earlier fiscal years but zero-funded in FY 88).

		Acid-Rain Related	
PI/Institution	Title/Duration/Total	Percent	Dollars/Year*
A. Clarke U. Hawaii	Real-Time Characterization of Tropospheric Acid Sulfate Aerosol 12 mos. $80,000	20%	Zero in FY 88
G. Black SRI	Photochemistry and Kinetics of Atmospheric Sulfur Species 12 mos. $76,500	10%	Zero in FY 88
J. Anderson W. Brune Harvard	Kinetic Studies of Sulfur, Halogen, Hydrogen and Oxygen-Containing Radicals 12 mos. $98,000	10%	$ 9,800
R. Dickerson U. Maryland	Convection and Tropospheric Trace Gases 12 mos. $180,000	10%	$ 18,000
A. Bandy Drexel U.	Development and Deployment of Analytical Instrumentation for Studying the Atmospheric Chemistry of Gaseous Sulfur, Nitrogen and Organohalogen Compounds in the Background Atmosphere 12 mos. $200,000	10%	$ 20,000
J. Prospero D. Savoie U. Miami	Measurements of Gaseous Nitric Acid and Ammonia in Marine Environments 12 mos. $45,000	20%	$ 9,000
P. Wine A. Hynes Georgia Tech	Laboratory Studies of Tropospheric Sulfur Chemistry 12 mos. $110,000	20%	$ 22,000
J. Seinfeld R. Flagan CIT	Fundamental Studies of Gas-to-Particle Conversion in the Atmospheric Sulfur System 12 mos. $115,000	10%	$ 11,500

PI/Institution	Title/Duration/Total	Acid-Rain Related	
		Percent	Dollars/Year*
C. Richardson U. Arkansas	A Laboratory Study of Sulfate and Mixed Sulfate-Nitrate Particles 12 mos. $51,000	20%	$ 10,200
W. Chameides Georgia Tech	The Development and Validation of a 3-D Chemical Transport Model for Combustion Sulfur from North America 12 mos. $50,000	20%	$ 10,000
W. Chameides Georgia Tech	The Chemistry of Clouds and its Role in Atmospheric Chemical Cycles 12 mos. $94,400	20%	$ 18,900
T. Novakov Lawrence Berkeley Laboratory	Cloud Chamber Study of SO Oxidation by Combustion 2 Products 12 mos. $125,400	20%	$ 25,100
P. Davidovitz Boston College	Heterogenous Reaction Rates of Cloud and Fog Droplets 12 mos. $125,000	20%	$ 25,000
L. Anderson U. Colorado (Denver)	Kinetics and Mechanisms of Important Atmospheric Reactions 12 mos. $54,000	10%	Zero in FY 88
B. Huebert SRI	Atmospheric Acidity: The Dry-Deposition of Nitric Acid Vapor 12 mos. $129,999	20%	$ 26,000
R. Charlson W.Zoller U. Washington	Acid-Base Chemistry of Marine Air 12 mos. $111,000	20%	$ 22,200
D. Davis R. Stickel Georgia Tech	A Vacuum-Ultraviolet Photofragmentation/Laser-Induced Flourescence Sensor for Measurement of Atmopheric Trace Gases 12 mos. $164,900	20%	Zero in FY 88
F. Rowland U. Cal., Irvine	Radioactive Tracer Investigations of Some Gas-Phase Reactions of Potential Atmospheric Importance 12 mos. $90,000	10%	$ 9,000

		Acid-Rain Related	
PI/Institution	Title/Duration/Total	Percent	Dollars/Year*
P. McMurry U. Minnesota	Experimental Studies of Gas-Aerosol Reactions 6 mos. $22,080	20%	$ 8,800
P. Hobbs D. Hegg L. Radke U. of Washington	Studies of Cloud Chemistry on the Mesoscale 12 mos. $19,999	20%	$ 4,000
A. Thompson Spelman College	The Chemical Composition of Precipitation at a Southeastern Urban Site 12 mos. $37,500	20%	Zero in FY 88
G. Vali U. Wyoming	Field Measurement of In-Cloud Sulfur Dioxide Oxidation 12 mos. $145,000	20%	$ 29,900
P. Steudler Marine Biological Laboratory	Carbonyl Sulfide and Carbon Disulfide Emissions from Temperate and Boreal Forests Along an Acid-Rain Gradient 12 mos. $127,400	20%	$ 29,500
D. Lamb Penn State	A Study of Microphysical Processes Associated with the Atmospheric Removal of Moisture and Trace Chemicals by Precipitating Clouds 12 mos. $100,000	10%	$ 10,000
D. Cronn Washington State	Organic Acids and Aldehydes in the Remote Atmosphere 12 mos. $66,000	20%	$ 13,200
J. Galloway U. Virginia	The Cycling and Deposition of Sulfur, Nitrogen and Organic Acids Over the North Atlantic Ocean 12 mos. $87,000	10%	$ 8,700
P. Hobbs U. Washington	Sulfur in Marine Atmosphere: A Continuation to the Global Atmospheric Chemistry Program 12 mos. $200,000	10%	$ 20,000
D. Jacobs Harvard	PYI: Transport and Chemistry of Trace Species in the Troposphere 12 mos. $62,500	20%	$ 12,500

		Acid-Rain Related	
PI/Institution	Title/Duration/Total	Percent	Dollars/Year*
C. Richardson U. Arkansas	A Laboratory Study of Sulfate and Mixed Sulfate-Nitrate Particles 12 mos. $51,000	20%	$ 10,200
W. Chameides Georgia Tech	The Development and Validation of a 3-D Chemical Transport Model for Combustion Sulfur from North America 12 mos. $50,000	20%	$ 10,000
W. Chameides Georgia Tech	The Chemistry of Clouds and its Role in Atmospheric Chemical Cycles 12 mos. $94,400	20%	$ 18,900
T. Novakov Lawrence Berkeley Laboratory	Cloud Chamber Study of SO Oxidation by Combustion 2 Products 12 mos. $125,400	20%	$ 25,100
P. Davidovitz Boston College	Heterogenous Reaction Rates of Cloud and Fog Droplets 12 mos. $125,000	20%	$ 25,000
L. Anderson U. Colorado (Denver)	Kinetics and Mechanisms of Important Atmospheric Reactions 12 mos. $54,000	10%	Zero in FY 88
B. Huebert SRI	Atmospheric Acidity: The Dry-Deposition of Nitric Acid Vapor 12 mos. $129,999	20%	$ 26,000
R. Charlson W.Zoller U. Washington	Acid-Base Chemistry of Marine Air 12 mos. $111,000	20%	$ 22,200
D. Davis R. Stickel Georgia Tech	A Vacuum-Ultraviolet Photofragmentation/Laser-Induced Flourescence Sensor for Measurement of Atmopheric Trace Gases 12 mos. $164,900	20%	Zero in FY 88
F. Rowland U. Cal., Irvine	Radioactive Tracer Investigations of Some Gas-Phase Reactions of Potential Atmospheric Importance 12 mos. $90,000	10%	$ 9,000

PI/Institution	Title/Duration/Total	Acid-Rain Related Percent	Acid-Rain Related Dollars/Year*
H. Sievering U. Colorado	Excess Sulfate in the Marine Boundary Layer 12 mos. $45,000	10%	$ 4,500
J. Weinstein-Lloyd SUNY-Old Westbury	The Chemistry of Hydrogen Peroxide in Cloudwater 12 mos. $42,400	20%	$ 8,500
J. Willey U. North Carolina, Wilmington	Organic Acids in Coastal North Carolina Rainwater 18 mos. $35,867	20%	$ 4,800
D. Jacob Harvard	Three-Dimensional Simulations of Long-Range Pollutant Transport 222 Rn and 210 Pb as Tracers 12 mos. $67,300	10%	$ 6,700
Sub-total Atmospheric Sciences Grant Research			$397,800
Acid-Rain Related Research at NCAR in FY 87			$200,000
Division of Atmospheric Sciences Total			$597,800

Division of Biotic Systems and Resources

		Acid Rain Related	
PI/Institution	Title/Duration	Percent	Dollars/Year*
J.D. Aber U New Hampshire	Chronic Nitrogen Additions to Forest Ecosystems 12 mos. $119,501	70%	$ 83,651
F.H. Bormann Yale	Collaborative Research: Hydrologic-Nutrient Cycle Interaction in Small Undisturbed and Man-Manipulated Ecosystems 12 mos. $183,687	30%	$ 55,106
C.T. Driscoll Syracuse U.	Collaborative Research: Hydrologic-Nutrient Cycle Interaction in Small Undisturbed and Man-Manipulated Ecosystems 12 mos. $104,000	70%	$ 73,000
T.J. Fahey Cornell U	Long-term Research at Hubbard Brook 12 mos. $399,841	20%	$ 80,000
A. Giblin Ecosystems Center, MBL	The Changing Sulfur Cycle of Lakes 12 mos. $206,765	80%	$ 165,412
G.E. Likens NY Botanical Garden	Collaborative Research: Hydrologic-Nutrient Cycle Interaction in Small Undisturbed and Manipulated Ecosystems 12 mos. $205,888	50%	$ 102,900
J.J. Magnuson U WI-Madison	Comparative Studies of a Suite of Lakes in Wisconsin 12 mos. $360,000	10%	$ 36,500
S.R. Carpenter U Notre Dame	Collaborative Research: Cascading Trophic Interactions and the Variance of Lake Ecosystem Productivity 12 mos. $109,000	20%	$ 21,800
D.A. Crossley U Georgia	Comparative Studies of Forested Watersheds at Coweeta Hydrologic Laboratory, North Carolina 12 mos. $364,968	30%	$ 109,500

		Acid Rain Related	
PI/Institution	Title/Duration	Percent	Dollars/Year*
J.F. Kitchell U Wisconsin Madison	Collaborative Research: Cascading Trophic Interactions and the Variance of Lake Ecosystem Productivity 12 mos. $97,910	20%	$ 19,600
	Subtotal Ecosystem Studies Grants Programs		$ 747,469
A. Chalmers U of GA	Arsenic in Thermal Spring Ecosystems: Distribution and Cycling 12 mos. $41,986	10%	$ 4,199
M. Davis J. Pastor U of MN	Reconstructing Forest Stand Histories and Soil Development From Paleoecological Evidence 12 mos. $135,922	20%	$ 27,184
C. Jones NY Botanical Garden	REU: Multiple Stress Interactions on Cottonwood and Their Chemical Mediation 12 mos. $6,220	100%	$ 6,220
N.W. Paerl U of NC	Physiological Ecology of Cynabacterial-microbial Consortia During Development of a Poliferation of Muisance Blooms 12 mos. $119,920	20%	$ 23,984
S.L. Rose O. Schimel C.S. U	Below Ground C and N Exchanges Between Plants Connected by Mycorrhizal Fungal Hyphae 12 mos. $47,550	10%	$ 4,755
O.R. Whitehead Indiana U	Paleoecological Investigation of Recent Acidification Trends in the Sierra Nevada 12 mos. $140,000	100%	$ 140,000
	Total Ecology Grants Programs		$ 206,342

		Acid Rain Related	
PI/Institution	Title/Duration	Percent	Dollars/Year*
J. Titus SUNY-Binghamton	Submersed Macrophytes: Three Levels of Response to Lake Acidification 12 mos. $53,000	10%	$ 5,000
A.J. Shaw Ithaca College	Genetic Basis of Heavy Metal Tolerance in the Moss, *Funaria hygrometrica* 12 mos. $55,044	10%	$ 6,000
J. Sperry U VT	Mechanisms of Xylem Embolism in Tree Species 12 mos. $170,000	5%	$ 8,500
	Total Population Biology Grants Program		$ 19,500
	Total Division of Biotic Systems and Resources		$ 953,811

Division of Earth Sciences

P.I./Institution	Title/Duration/Total	Acid Rain Related Percent	Acid Rain Related Dollars/Year*
R. Defries NAS/NRC	Support for Scientific Committee on Problems of the Environment (SCOPE)	100%	$ 5,000
H. Mullins Syracuse U	Paleolimnology and Climatology of New York State Finger Lakes	50%	$ 31,638
S. Epstein C.I.T.	Oxygen, Hydrogen, Carbon, Silicon and Nitrogen Isotope Studies of Natural Occurring Materials	20%	$ 36,506
L.F. Roland Morehouse College	An Undergraduate Research Program in Earth and Atmospheric Science	Continuing Grant, No funds in FY 88	
E. Barron Penn State	The Global Water Cycle: Past, Present, and Future	50%	$ 1,875
L. Kump Penn State	Coupled Models of Geochemical Cycles and Climate	30%	$ 20,000
S. Parker NAS	Opportunities in the Hydrological Sciences (Report)	20%	$ 8,000
J. Harsh Wash State U	The Stability and Surface Chemistry of Allophane and Imogolite	30%	$ 30,403
	Total Division of Earth Sciences		$ 133,422

Division of Fundamental Research in Emerging and Critical Engineering Systems
Environmental Engineering Program

		Acid-Rain Related	
PI/Institution	Title/Duration/Total	Percent	Dollars/Year*
G.J. McRae Carnegie-Mellon	PYI—Analysis and Optimization of Environmental Models 12 mos. $62,500	100%	$ 62,500
E.L. Peck Hydex Corp.	SBIR—Phase II. Remote Measurement of Haze Layers Over Land 24 mos. $199,605	100%	Zero in FY 88
NRC/NAS	Support for the Scientific Committee on Problems of the Environment (SCOPE) (Funded jointly with other NSF-Programs for a total of $70,000—entries listed separately.)	100%	$ 5,000
C. T. Driscoll Syracuse Univ.	PYI— Drainage Basin Ecosystem Response to Inputs of Sulfuric and Nitric Acids in the Northeastern United States 12 mos. $62,500	100%	$ 62,500
P. S. Eagleson Mass. Inst. of Technology	Equilibrium Models of Climate-Soil-Vegetation Interaction 12 mos. $99,374 including $36,476 from FY 1987	100%	Zero in FY 88
K. Lal Gauri Univ. of Louisville	Effects of Air Pollutants on the Deterioration of Marble 24 mos. $133,540	100%	Zero in FY 88
E. Christenson U. WI-Milwaukee	Historical Fluxes of Pollutants from Deconvolution of Sedimentary Records 24 mos. $191,322	100%	$ 102,901
S.A. Batterman Texas A&M	Research Initiation: Modeling and Estimation of Soil/Air Contaminant Flux 24 mos. $59,923	100%	$ 29,960
	Total of Environmental Engineering Grants Program		$ 262,861

Division of Social and Economic Sciences

PI/Institution	Title/Duration	Acid Rain Related Percent	Acid Rain Related Dollars/Year*
T.C. Meierding	Marble Weathering and Air Pollution in Eastern North America	%	$ 26,902
	Total for Social and Economic Sciences		$ 26,902
	Total for the National Science Foundation		$1,974,796

*Rounded to nearest $100.

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

OFFICE OF THE
DIRECTOR

December 6, 1988

Honorable Robert A. Roe
Chairman, Committee on Science,
Space and Technology
House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

In the report accompanying H.R. 4418, the NSF Authorization Act, the Committee requested a report on actions taken in response to the 15 recommendations in the National Science Board Report, "The Role of the National Science Foundation in Polar Regions." The Committee requested, further, that the report include a review of environmental protection practices in the Antarctic. I am pleased to provide this report.

Sincerely,

Erich Bloch
Director

Enclosure

Copy to:
Honorable Manuel J. Lujan
Honorable Doug Walgren
Honorable Sherwood Boehlert

REPORT OF NSF ACTIONS
PURSUANT TO THE NATIONAL SCIENCE BOARD REPORT
ON "THE ROLE OF THE NATIONAL SCIENCE FOUNDATION IN POLAR REGIONS"
AND ON ENVIRONMENTAL MATTERS
TO THE
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
CONGRESS OF THE UNITED STATES

In the report accompanying H.R. 4418, the NSF Authorization Act, the Committee requested that "NSF provide a report by December 1, 1988, on actions taken in response to the 15 recommendations in the report of the National Science Board, 'The Role of the National Science Foundation in Polar Regions.'" The Committee particularly requested that the report include a review of the NSF environmental protection practices in the Antarctic now in effect and proposed changes, if any.

This report lists the fifteen NSB recommendations and the actions that have been taken thus far on each of them. Environmental practices and proposed changes are addressed in an "Environmental Protection Agenda," highlights and discussion of which are included in this report.

NSF Role in Polar Regions

The National Science Board accepted the Report of the NSB Task Committee on NSF's Role in Polar Regions on June 19, 1987. At that time, a request was made to the Director to prepare a plan of action to respond to the Report's recommendations. In June 1988, a staff document was issued which presented an Implementation Plan. This report to the Congress draws heavily on the Implementation Plan.

In introducing its recommendations, the NSB Committee noted NSF's institutional responsibilities in the Polar Regions:

> There is important science in the national interest to be done in the Arctic and the Antarctic. The NSF operates the U.S. Antarctic Program and has been designated by the Arctic Research and Policy Act to coordinate basic research in the Arctic; therefore, the agency has a primary responsibility for polar science.

Recommendations of the Board Committee and actions in response to them follow:

1. In both polar regions, research programs must be dictated by the science and engineering needs and opportunities rather than available logistics. The Committee recommends that logistics derive from and support the scientific research program rather than dictate that program.

Significant research that can only be done in the polar regions includes for example, polar effects of global paleoclimates, studies of arctic haze, relationship of interannual variations of sea ice to climate, production and circulation of deep water masses, study of the tectonic role of Antarctica in the breakup of Gondwana, studies of environmentally stressed (extreme cold) organisms, evolution of biological species inhabiting polar regions, and functioning of polar terrestrial and marine ecosystems.

Significant including: improvements in logistics and facilities are sought,

- o planning for coordination of arctic logistics, including a directory of Federal logistics capabilities which is currently being prepared,
- o construction and upgrading of laboratory facilities at all antarctic stations, and
- o tailoring of ship and aircraft support to meet science needs.

More specifically:

- o Science input for the replacement laboratory at McMurdo Station was obtained by the architect/engineering contractor at several regional meetings with potential users.
- o South Pole logistics have been revised to provide increased support for astronomy and astrophysics.
- o In preparing to obtain the new research vessel with icebreaking capability, NSF sought advice from the University National Oceanographic Laboratory System (UNOLS), the Polar Research Board, and the Division of Polar Programs Advisory Committee.

2. The Committee recommends that the NSF establish and oversee the operation of a network of research support centers for the polar regions. These centers would be supported by the NSF and managed by universities or private organizations.

Steps have been taken to realize this objective:

- The new polar ice coring activity at the University of Alaska, Fairbanks, is one potential center.
- A consortium, the Arctic Research Consortium of the United States, has been formed that has the potential to coordinate support center activities.
- The recently issued RFP for an antarctic support contractor specifically allows for the transfer of key science support activities at McMurdo Station and elsewhere to an academic consortium or institution.

3. The Committee recommends that a logistics program be established for the Arctic to support NSF scientists and research projects conducted in the northern polar regions. All logistic support facilities and equipment in both the arctic and antarctic programs should be clearly identified as belonging to the NSF and part of the NSF program. The NSF presence and leadership in research at both poles should be visible and recognizable, thereby strengthening the research network through identification with the NSF.

Unlike the Antarctic, the Arctic has an indigenous population with associated infrastructure of transportation, shelter and the like. Some centralization of logistic support may result from the location of the ice coring office at the University of Alaska as well as from establishment of the new arctic consortium. Much logistics, however, is handled more efficiently through individual grants and existing central arrangements such as UNOLS, which coordinates ship use in the Arctic as well as other areas, and the Department of Interior's office for the coordination of leasing of aircraft.

The Foundation has been assigned as lead agency for coordination in the Arctic, but it is only one of several agencies supporting substantial research and monitoring efforts. In the Antarctic, where it manages the U.S. program, the Foundation can and is doing much more to increase the visibility of its role. However, in both regions NSF places emphasis on maximizing the effectiveness of U.S. research.

4. As mandated in the Arctic Research and Policy Act, an assessment of research needs for the Arctic and development of a plan to address those needs are in progress. A similar effort should be undertaken for the Antarctic.

> The Committee recommends that the NSF take the initiative in coordinating the development of an interagency national polar research plan.

The arctic plan mentioned in recommendation 4 was published in July 1987. With respect to the Antarctic, the Implementation Plan for the NSB report notes (page 26):

> The U.S. Antarctic Program (USAP) is planned, budgeted for and managed by NSF through a special appropriation. Other Federal agency participation in antarctic research occurs in one of three ways:
>
> o Unsolicited proposals to NSF from investigators in other agencies which compete for program funds through standard peer review.
>
> o Directed short-term programs, with their own budgets, approved by the Antarctic Policy Group. These programs must be coordinated within the framework of the NSF logistic support system.
>
> o Joint programs with NSF closely related to ongoing USAP research projects and coordinated for mutual benefit at no additional cost to the USAP.

The NSF's Division of Polar Programs reorganized its Polar Coordination and Information Section to include an Arctic Staff and an Antarctic Staff. This organizational arrangement should facilitate development of a combined Polar Plan.

> 5. The Committee endorses and encourages the conduct of research in the social, health, and medical sciences in relation to the extreme polar environments and for which the polar regions are uniquely suited. The Committee recommends that the NSB encourage the National Institutes of Health and other appropriate agencies to support increased health and medical science research in polar regions. In addition, we recommend that, in cooperation with such health and medical research, the NSF support basic social sciences research in polar regions.

The Chairman of the National Science Board wrote to the Director of the National Institutes of Health and the Assistant Secretary for Health, Department of Health and Human Services, forwarding the NSB Report, calling attention to this recommendation and noting that the senior Foundation contact is the Assistant Director for Biological, Behavioral and Social Sciences (BBS).

The Assistant Secretary's response indicated the readiness of the NIH and other components of the Public Health Service to cooperate and designated a DHHS contact point. Thus the groundwork for the medical and health science effort has been laid. With respect to the social sciences, the Interagency Arctic Research Policy Committee (IARPC) is preparing a coordinated social sciences implementation plan. NSF staff from DPP and BBS are participating. That initial plan should be available shortly.

> 6. Further, the Committee recommends that research on the culture, history, linguistics, archaeology, and physical anthropology of arctic peoples be established in the NSF as an identified and appropriately staffed program within the Division of Polar Programs.

No funds were budgeted for arctic social sciences in FY 1988 or FY 1989 within the Arctic Research Program administered by DPP. However, a joint review procedure has been developed by DPP and BBS to implement this recommendation as funds become available.

The National Academy of Sciences/Polar Research Board's Committee on Arctic Social Science is providing scientific guidance.

The IARPC plan mentioned above in connection with recommendation 5 will also be applicable here.

> 7. Dedicated polar research vessels are an urgent and critical need. The scientific and strategic position of the United States in the polar regions has been seriously, if not dangerously, eroded because the country lacks modern ice-capable vessels dedicated to polar research in the Antarctic and Arctic. Therefore, the Committee recommends that a research vessel with icebreaking capability be acquired for the U.S. Antarctic Program, and that a research vessel capable of scientific and engineering research in arctic seas also be acquired.

As a first step in implementing this recommendation, the Foundation sought to lease, via its antarctic support contractor, ITT/Antarctic Services Inc., a research vessel with icebreaking capability (RVIB). This procurement was cancelled just prior to making an award as a result of "Buy American" language in the Foundation's FY 1989 appropriation. Recompetition of the procurement is proceeding, and obtaining the RVIB is a major step in responding to this recommendation.

8. Major logistic components of the Antarctic Program need upgrading, including the McMurdo science laboratories, living quarters at South Pole Station, LC-130s, and helicopters. Private organizations operating on the North Slope of Alaska have acquired expertise in the construction and maintenance of facilities in the polar environment. The Committee recommends that the cooperation of private organizations and industry be sought in the construction of facilities and provision of logistic support in the Arctic and Antarctic.

NSF/DPP use of technology developed in the Arctic for antarctic operations includes:

- The use of a component of the U.S. corporation which helped build and maintain the DEW line in the Arctic as the major civilian contractor for logistic support and operations in Antarctica.
- The use of arctic-experienced architect and engineering firms for antarctic facilities. For example an Alaskan firm was recently selected as the design contractor for an air transportable field laboratory.
- The recent purchase of two Hagglunds Bv206 tracked vehicles developed for arctic travel over snow.

9. The Committee recommends that health, safety, and environmental protection practices for polar research programs, especially the Antarctic Program, be studied and upgraded where necessary.

The report of the U.S. Antarctic Safety Review Panel, "Safety in Antarctica" (June 30, 1988) is a comprehensive document dealing with environmental practices as well as safety and health. Its 72 recommendations provide guidance for NSF's future actions in these areas. Two of these provide an indication of the Report's content.

The Panel recommended that:

> the Safety, Environment and Health Officer [recommended in the report] should develop an environmental clean-up master plan for all stations. Annual reports should be submitted to the Director, Division of Polar Programs and the National Science Foundation Director on the status of safety, environment and health programs and their impact on Antarctica...
>
> the National Science Foundation seek a one-time special allocation to support an expedited environmental clean-up of McMurdo.

> This special fund should be budgeted to support the collection, preparation, retrograding and/or proper disposal of all non-combustibles.

Also, NSF has issued and received comments on an "Environmental Protection Agenda; United States Antarctic Program." The comments are now being considered and revisions made so that the agenda can provide effective guidance for program actions. This agenda will be addressed further in the environmental protection portion of this report.

> 10. The Committee endorses plans for the use of satellites in polar studies and their scientific use as proposed by other agencies. As the recommended interagency national polar plan is developed the Committee recommends that other forms of remote and/or automated data collection be funded, and, once in place, fully utilized.

Satellites are used in the Antarctic Program for inter- and intra-continental communications--voice, message and data. They are also vital for operational weather forecasting in Antarctica and valuable for sensing and observations for ocean and atmosphere research in the polar regions. For example, the satellite-borne Total Ozone Monitoring Spectrometer (TOMS) provides the overall ozone depletion data, with which ground-and balloon-based observations of the first through third National Ozone Expeditions in the Antarctic are compared.

In response to the Safety Panel's report, search and rescue satellite links are being used in Antarctica on a trial basis.

Remote and/or automated data collection systems and components are in various stages of development and use:

- Backscatter radars for examination of upper atmosphere phenomena are in use in both polar regions.
- Automatic weather stations are in use, with new air-droppable stations being developed.
- Development and procurement of automatic geophysical observatories for surface-based observations of upper atmosphere phenomena is under way.
- Procurement of Remotely Operated Vehicles (ROV's) for unmanned exploration and biological, glaciological, and sedimentological studies of marine and freshwater environment is being undertaken for both scientific and safety reasons.

- Automated ultraviolet monitoring systems have been installed at South Pole, Palmer, McMurdo, and at Ushuaia, Argentina.

11. The Committee commends the U.S. Navy's VXE-6 Squadron on the extraordinary job it is doing for the U.S. Antarctic Program. The science could not be accomplished without the dedication, skill, and willingness to serve demonstrated by these fine fliers and support crews. They should remain an integral part of the U.S. Antarctic Program. However, the Committee recommends that the remaining support functions currently provided by the U.S. Naval Support Force Antarctica be reviewed by NSF management for possible transfer to civilian contractors as suggested by the U.S. Navy, if such transfer proves to be the most efficient and cost-effective option.

By agreement of the Navy and NSF, and with Antarctic Policy Group approval, the Naval Support Force is being reduced by 74 billets and the associated functions transferred to Antarctic Services, Inc. This change will make available billets to allow an increase in VXE-6 personnel to restore flight hours to the level of the early 1980s to meet science program needs.

12. The Committee recommends that the NSF role in the development of polar policy be increased. The NSF should become more active in policy analysis and decision making on arctic and antarctic issues. Potential policy issues and problems should be anticipated and options for dealing with them developed.

NSF's Arctic and Antarctic Staffs contribute to policy issue and option analysis in the polar regions. In addition, with respect to the Arctic:

- The Director of NSF is Chairman of the Interagency Arctic Research Policy Committee and DPP chairs staff and working group activities leading to implementation plans. The Director was very influential in the formulation of the Arctic Research Plan and in its successful completion.
- The Director is also an ex-officio member of the Arctic Research Commission and is an active participant in its deliberations.

- The NSF Assistant Director for Geosciences and DPP staff are participating with the Interagency Arctic Policy Group (IAPG) and the Arctic Research Commission in discussions on forming an International Arctic Science Committee. A report on the need for such a Committee is forthcoming and meetings are likely to occur in 1988.

- The Division Director, DPP is the NSF representative on the Interagency Arctic Policy Group.

- The Director and staff are involved with the State of Alaska, its Governor, and Science Advisor on such matters as the Alaskan Science and Technology Foundation and joint Federal-State research.

With respect to Antarctica:

- NSF is one of the three agencies composing the core membership of the Antarctic Policy Group. The Assistant Director for Geosciences is the NSF member of the Group. At the Foundation's request, the Group is now addressing tourism in Antarctica (see recommendation 13).

- The Division Director, DPP, has provided leadership in establishing an international working body, Managers of National Antarctic Programs. Objectives of the body are to facilitate discussions on common problems and their solutions, and to stimulate increased and regular, direct contact and communication among national program managers.

- NSF/DPP staff participate as delegates in Antarctic Treaty Meetings.

13. Tourism in Antarctica is increasing and can adversely affect the science program. When search and rescue operations become necessary, time, resources and facilities planned for science activities are lost, and life and property endangered. Issues related to tourism and responsibility for tourists should be addressed by the Antarctic Treaty Nations; however, the NSF should take a leading role in these deliberations. Stronger recommendations to the Treaty Nations, through the Antarctic Consultative Treaty Meetings, are encouraged. New agreements and procedures are needed; for example, consideration should be given to licensing to assure minimum standard of preparedness, indemnification or bonding, assignment of responsibility to countries for their citizens, and issuance of international visas. The Committee recommends that national

legislation be sought to ensure that tourists are properly insured or indemnified before they visit Antarctica. Further, the Committee encourages the assistance of nongovernmental groups such as the Antarctican Society, the Explorers Club, and the Alpine Club in developing a voluntary, responsible set of guidelines for tourism in the Antarctic, specifically, and in polar regions in general.

With respect to Tourism in Antarctica:

- An analysis of the constitutionality and feasibility of such legislation is being conducted by the Office of General Counsel, NSF.
- The Antarctic Policy Group is conducting a study of existing Treaty recommendations and national legislation with regard to further actions on the tourism issue. Included is the strengthening of the regulations and enforcement under the Antarctic Conservation Act.
- The Director and staff members of DPP are working through both the newly organized Managers of National Antarctic Programs group and the Antarctic Consultative Treaty Meetings process to formulate a code of conduct for tourists in Antarctica. An outline of a proposed code has been prepared by NSF and is the basis of ongoing discussions among national program operators and Treaty Consultative Parties.
- The DPP Division Director and staff have met with tour operators to discuss the environmental, safety and program impact of the tours.

14. The Committee recommends that basic engineering research be conducted in the polar regions and that it be a specifically targeted research component of such programs to develop the engineering knowledge required for operation in the polar environment. The appropriate NSF unit to undertake basic engineering research in cold regions is the Engineering Directorate.

Engineering Directorate and DPP personnel are working together to implement this recommendation. A workshop with participants from academia, government and professional societies is being held in December, 1988 to further refine research priorities.

15. Finally, and most importantly, because of the exciting and critical science that can and should be done in the polar regions, as shown in the Committee's review of research opportunities in polar science, we strongly recommend that the funding for polar science wherever it is presently supported within the NSF, be increased to a level twice that budgeted for Fiscal Year 1988 within the next 3 years and that the suggested logistic support be put in place as scientific opportunities and needs dictate.

In FY 1989, the budget for the Arctic Research Program is $10.3 million, a $2 million increase over the previous year. This is a substantial step toward doubling the budget for arctic research. However, given the many priorities within the Directorate for Geosciences, which includes the Arctic Research Program, it is questionable whether this rate of budget increase can be maintained over the next few years.

The overall increase allowed by Congress for FY 1988 to FY 1989 for the U.S. Antarctic Program was 5.0 percent, which was smaller than requested. In spite of this, the Antarctic Research Program received the full $2 million, or 14.8 percent increase requested. However, the increasing costs of operations, construction and procurement necessary to provide science support and to meet environmental protection needs may make it difficult to achieve the doubling of funds for antarctic research.

Environmental Protection Practices

Significant activities are under way to continue improvement of U.S. Antarctic Program environmental protection. These actions respond to both the NSB and Safety Panel reports. An Environmental Protection Agenda was published for public comment in October, 1988 and is currently being revised in light of public comments.

The following material on current practices is drawn largely from this agenda.

Examples of waste-management activities at McMurdo Station include:

- Extensive retrograde of metal scrap, old vehicles, pipe and tubing, broken tools, wiring, batteries, tires, and construction materials to United States.
- General site cleanup. This has been facilitated by the introduction of dumpsters strategically placed around the station, increased indoor storage for construction materials and other supplies, and halting the practice of outside storage of ship off-load materials.

- Paper and wooden packing materials burned in hot oil-fueled fires at the dump, and ashes buried.
- Expansion of Winter Quarters Bay (WQB) cleanup, with extricated steel scrap being retrograded to the U.S. and remaining materials being compacted and covered where possible. This continuing cleanup has been advanced by ceasing operation of the WQB snow removal dump area.
- Ocean dumping of scrap metal suspended in August 1988.
- Waste lubricants sealed in drums and retrograded to the United States. Fuel line upgraded. New garage oil separator installed to keep oil from entering the sewer system.
- Sewer-system expanded. Utility lines are being consolidated. Liquid waste is to be diluted with waste brine from distillation plant prior to flushing to sea; a macerator is being installed.
- Combined electrical generating plant and water-distillation plant reduces total fuel requirement, fuel loss, and emissions.

Waste-management activities at Palmer Station include:

- As of August 1988, all ocean dumping suspended, and material formerly dumped retrograded.
- Small metal scraps crushed, and baled for retrograde.
- Waste glass broken into small chips and sealed in drums.
- Garbage sealed in drums to be retrograded to South America for subsequent disposal.
- Waste lubricants sealed in drums for retrograde.
- Scrap metal being removed from dump sites.
- Paper replacing foam or other plastic packaging where possible.
- Wood/paper products burned. Because station population is about 5% that of McMurdo the volume of trash is much smaller.
- Waste tires and batteries retrograded.

Activities at Amundsen-Scott South Pole Station include:

- Waste buried in deep trenches.

Activities at Marble Point Camp include:

- Contents of hundreds of steel drums retrograded to McMurdo or burned on site; drums crushed and retrograded to McMurdo.
- Burial pits covered.
- Sanitary wastes retrograded to McMurdo.
- Solid waste retrograded to McMurdo to the extent practicable.

Activities at Hallett Station include:

- Joint U.S.-New Zealand cleanup and site-rehabilitation program begun eight years ago following station closure approaching completion.

Waste-management at field camps includes:

- Solid wastes transferred from field camps to coastal stations for local disposal or, if practical, for retrograde to the U.S.
- Liquid wastes transferred from field camps to coastal stations for local disposal if field conditions preclude safe disposal in deep snow trenches.

The Environmental Protection Agenda indicates areas where the Foundation recognizes that action is needed. An announcement printed for comment in the Federal Register summarized these areas as follows:

- Planning for Environment Management

  Biennial, Program-wide review is planned in order to consider site planning and other support requirements that might impinge on science or impact the environment; to consider the need for, adequacy, and implications of, environmental monitoring studies for thoughtful environmental assessment and management; and to update and revise this Agenda. Environmental criteria shall be made explicit in the ordinary running of USAP. They are being incorporated where appropriate in work statements, and are being reviewed and updated for adequacy.

- Legal Review

  The environmental responsibilities of all parts of USAP are now being analyzed and clarified through appropriate legal guidance from NSF's Office of the General Counsel (OGC). This will entail continued examination of pertinent environmental laws and regulations, related maritime law, and USAP program planning and policy. NSF has begun efforts here that include hearings on, and possible revision of, tourism-related regulations under the Antarctic Conservation Act.

- Environmental Assessments and Impact Studies

  Guidance from program management is ensuring that environmental assessments and impact studies are conducted as needed. Environmental assessment guidelines tailored to the context of USAP are in preparation.

  USAP's 1980 Environmental Impact Statement is being reviewed for possible update. The Division has invited Federal agencies and other organizations to comment on issues to be addressed in the review of this programmatic impact statement and it has begun analyzing the responses.

- Environmental Awareness

  Environmental awareness efforts are being increased both within USAP and outside. Efforts now under way include production of audio-visual briefing aids and development of a reference guide. Program participants are being made more familiar with requirements of antarctic environmental protection and conservation through enhancements to the USAP Personnel Manual.

  Administrative measures to sustain environmental awareness should include environmental inspections at facilities, environmental training, recognition and awards for accomplishments in antarctic environmental protection, management, and conservation, and negative sanctions where necessary.

- Facilities and Logistics

  The existing McMurdo Station Long-Range Development Plan will be updated to reflect the current analysis of USAP's facilities requirements. The updated document is intended to include a Master Plan for development, an updated requirements plan, and an implementation plan. The updated plan will, if necessary, include an environmental impact assessment of McMurdo's planned development. The plan will be subject to all appropriate review processes and to periodic updates as changes occur. Management of solid wastes at McMurdo includes import limitations, litter control, on-site waste disposal, and retrograding. These functions will be reassessed through a formalized systems approach to waste management. Development of this approach will take account of the entire waste cycle.

  Over the next few years, attention will also be given to management of McMurdo's liquid wastes and to problems of waste management at other USAP stations.

The studies, facility improvements, and administrative measures that emerge as the environmental agenda are likely to be expensive and time consuming. But these are necessary costs of U.S. presence and research in Antarctica. The costs of fulfilling of the recommendations in the NSB's "Role of the National Science Foundation's in Polar Regions" report are also formidable. However, effective research in the polar regions is important in a number of fields. Not the least of these is the understanding of past and future changes in global climate. Key contributions can be made in both polar regions through the study of the climate record for the past 200,000 years available from ice cores, through investigation of air-sea-ice interactions and their effects on weather and climate, and through examination of the dynamics of glaciers and ice sheets and their potential effects on sea level.

The impact of climate changes such as the biological effects of the antarctic ozone hole is yet another important research topic that can have implications outside the Antarctic.

Fulfilling the recommendations of the NSB report is a formidable task that will require the cooperation of the Foundation, the Administration and the Congress.

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

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DIRECTOR

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Honorable Robert Roe
Chairman
Committee on Science, Space, and Technology
House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

In the report accompanying H.R. 4418, the NSF Authorization Act for Fiscal Years 1989 and 1990, the Committee requested a report by January 1, 1989 listing NSF funding in Fiscal Years 1987 and 1988 for support of research at non-NSF sponsored supercomputer centers. This information is contained in the report attached to this letter.

For FY 1989, NSF has continued the program of providing access to advanced computing capabilities not available at our national centers. As in the past, the NSF scientific directorates will be closely involved in the award process.

Sincerely,

Erich Bloch

Erich Bloch
Director

Enclosure

cc: Honorable Robert Walker ✓
Honorable Doug Walgren
Honorable Sherwood Boehlert

REPORT ON OTHER SUPERCOMPUTER ACCESS

National Science Foundation
December 14, 1988

Introduction

In the legislative report accompanying the FY 1989 Authorization Bill for the National Science Foundation, the House Committee on Science, Space, and Technology requested a comprehensive review of the Foundation's support in FY87 and FY88 for research at non-NSF supercomputer centers. The Committee requested aggregate funding levels, as well as a breakdown of support by Directorate and by computer center.

FY87 Expenditures and Usage

In FY 1987 the Directorates for Biological, Behavioral and Social Sciences (BBS) and Computer and Information Science and Engineering (CISE) purchased computer resources at non-NSF centers as shown in Table I.

Table I

NSF Directorate	Colorado State University	Purdue University	University of Minnesota
Bio. Behav. & Soc. Sci.		$239,000	$45,000
Comp. Info. Sci. & Eng	$200,000	$200,000	$1,000,000
Total	$200,000	$439,000	$1,045,000

Total expenditures were $1,684,000. The FY87 funds from the CISE Directorate supported ongoing projects from all NSF Directorates during the completion of the NSF "Phase I" program of supercomputer access. Table II contains an estimated breakdown of the relative percentages of total NSF dollars as indicated in Table I.

Table II

Phase I Center Usage by NSF Directorates - FY87

NSF Directorate	Colorado State University	Purdue University	University of Minnesota
Bio. Behav. & Soc. Sci.	11.1	59.3	4.6
Comp., Info. Sci. & Eng.	34.0	1.6	6.6
Engineering	4.1	6.5	10.4
Geosciences	1.4	0.8	2.5
Math, Physical Sci.	49.5	31.9	74.3
International	0.0	0.0	1.5
Total	100.0%	100.0%	100.0%

FY88 Expenditures and Usage

In FY88, funds were allocated directly to the Directorates to purchase computer resources as shown in the following Table III.

Table III

FY88 Expenditures by NSF Directorate

NSF Directorate	Purdue University	University of Minnesota
Bio., Behav., & Soc. Sci.	$551,000	$159,000
Comp. Info. Sci. & Eng.		97,500
Engineering		131,250
Geosciences		17,250
Math, Physical Sci.		1,095,000
International		
Subtotal	$551,000	$1,500,000

Total support at non-NSF supercomputer centers in FY88 was thus $2,051,000. With the $1,684,000 from 1987, the NSF support totals $3,735,000 over the two Fiscal Years.

NATIONAL SCIENCE FOUNDATION
WASHINGTON. D.C. 20550

nsf
OFFICE OF THE
DIRECTOR

March 3, 1989

MAR 10 1989

Honorable Robert Roe
Chairman, Committee on Science,
Space and Technology
House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

I am pleased to submit this report on the technology transfer activities at the National Science Foundation. This report is requested in House Report 100-649 which accompanies the 1989 NSF Authorization Act.

Since its inception in 1950, the Foundation has played an important role in maintaining and strengthening the Nation's scientific knowledge base. While the transfer of scientific knowledge is a component of all of the Foundation's programs, the report highlights those activities which focus on the technology transfer process as it involves interaction between industry and academia.

I trust the report will help you in assessing our technology transfer activities and serve as a stimulus for suggestions.

Sincerely,

Erich Bloch
Director

Enclosure: Technology Transfer: A Report
to the Congress

Copy to: Honorable Robert Walker

TECHNOLOGY TRANSFER: A REPORT TO THE CONGRESS

1.0 TECHNOLOGY TRANSFER

1.1 Introduction.

This is a report on the Technology Transfer activities at the National Science Foundation, as requested in House Report 649[1] which accompanies the 1989 NSF Authorization Act. The response covers existing activities at the Foundation which seek to bring new knowledge, gained through basic and applied research, to bear on the development of new technology. It concludes with options which, since they affect policy, are not recommendations until they are reviewed and considered by the National Science Board.

1.2 Methodology.

NSF staff, to make the present response more informative, followed a specific Congressional suggestion; it explored its own role as well as the larger context for technology transfer with selected institutional representatives. Organizations contacted included the National Academy of Sciences, American Association for the Advancement of Science, and a number of industrial and trade associations. Their advice on existing activities, as well as proposals for new programs was valuable and useful. The report further presents additional concepts and techniques for transfer of existing knowledge from universities to industry.

1.3 Long Standing Role.

As part of its charter, the National Science Foundation has, since its inception in 1950, played an important role in Federal efforts to maintain and strengthen the Nation's knowledge base. Because the transfer of knowledge between the academic and the industrial sector is a vital ingredient in enhancing the country's industrial competitiveness, NSF has sponsored programs to enhance that transfer. Reflecting changing national priorities, there has been a gradual shift so that NSF, while increasing its support for basic research, has also assumed a greater concern with technology and the transfer of knowledge, without competing with other Federal agencies which have explicit applied research missions.

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[1] 100th Congress, p.23.

1.4 Basic Research.

The Foundation supports basic research, predominantly at universities, and promotes science and engineering education. In the context of the national research and development effort, the Foundation's $1.7 billion 1988 budget is only slightly more than one percent of the $132 billion[2] of the estimated national 1988 R&D effort. Given this relatively small direct role in the overall funding picture, NSF seeks to leverage its resources to affect the much larger national research effort, and to serve as a facilitator in the technology transfer process. How the Foundation works towards its objectives of training, leverage of technology, and enhancement of university/industry relations is detailed in later sections of this report.

1.5 Toward Commercial Products.

At NSF, technology transfer is a stimulating and facilitating process to move research results and technological innovations from the laboratory, from government or university sponsorship to the private sector which then will produce commercially successful products. Another, broader view of technology transfer is that of a continuum of interrelated events between academic, business, and government partners. It is a dynamic process, involving invention, translation to meet commercial needs, and finally commercialization. It requires management and commercial resources as well as the assessment of the market for the potential product. Because the main activities of the Foundation are devoted to the support of basic and applied scientific research and science education, the role of the Foundation in technology transfer has been limited to the transfer of knowledge between the universities and industry.

Two Taxonomies. 1. In a recent paper, Dr. Ralph Gomory (a senior vice president at IBM) and Dr. Roland Schmitt (president of Rensselaer Polytechnic Institute)[3] described two types of technology transfer. The first reflects the process of sequential discovery as in the case of the semi-conductor. Here the verification of quantum mechanics in solids, and the developments in solid state physics are the rungs of the "ladder" of the technology. The second is evolutionary technology transfer; small incremental changes in an existing technology result over time in what might be considered an essentially new product. NSF programs address both processes.

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[2] "Highlights," Science Resources Studies, NSF 88-303, National Science Foundation, Washington, D.C. February 1988.

[3] Gomory, R.E., Schmitt, R.W., "Science and Product," Science, Vol. 240, 27 May 1988, pp 1131,1132, pp 1203,1204.

2. A different taxonomy considers technology transfer in terms of Push or Pull. "Push" is exemplified by NSF which sponsors basic research, then seeks, within limits, to "push" into the industrial sector, i.e. facilitate the use of those results which look useful. While "pull" has not been used to the same extent by NSF because it is based on the expressed needs of those who seek new solutions, the Presidential Young Investigator Awards (PYI) program described in Section 2 is one example of this approach.

1.6 NSF Programs.

Programs at the National Science Foundation, with technology transfer as one of their components, range from the new Science and Technology Centers and the SBIR program, to the Engineering Research Centers and the Industry/University Cooperative Research Centers which infuse industrial needs into the research goals. In addition there are projects to improve the archiving and distribution of information in the disciplinary, cross disciplinary, and international programs. The specific functions of these activities with respect to technology transfer are discussed next.

2.0 TECHNOLOGY TRANSFER ACTIVITIES AT NSF

Because of the Foundation's role in the sponsorship of university research and science education, technology transfer activities at NSF try to build working relationships between research in industry and at universities to leverage federally sponsored research. These Foundation programs seek transfer of knowledge from one researcher to another and from the research community to industry. This approach to technology transfer is unique to the Foundation among Federal agencies.

Technology transfer in other Federal agencies[4] differs significantly from the Foundation's activities. These agencies deal in technology spin-off, common to NASA and DOD, and technology utilization, characteristic of Energy and Agriculture. Technology spin-off means that the technology is to be used in the private sector for purposes other than those for which it was originally intended. Technology utilization means the technology usually is created specifically for private sector application; the agency will not accomplish its principal mission unless the technology transfer is effective.

The special character of technology transfer at the Foundation derives from its specific focus and the network of individuals it sponsors in basic research. NSF's commitment is to supporting basic scientific research at universities. Technology transfer is an important byproduct of this mission. Of the estimated $15 billion[5] devoted nationally to basic research, the Foundation accounts for just over ten percent. Then, to derive additional benefits from this relatively small contribution to the national basic research budget, the Foundation stimulates knowledge or technology transfer.

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[4] "Guidebook for Technology Transfer Managers," Meridian Corporation, Alexandria, Va. June 1987.

While the purpose of this report is to explicate the Foundation's more formal technology/information transfer activities, there are many unforseen instances of technology or product development stemming from basic research. For example, a super-computer aided laser flow visualization technique supported by the Foundation has been adopted by General Motors for combustion research. Basic research on lightning led to a lightning direction finder, now a worldwide, multi-million dollar market. Yet another technology transfer anecdote is the Foundation's research project on Doppler radar which led to a downburst and windshear pilot warning system. Bearing these technology transfer successes in mind, the following sections outline the more structured processes at the Foundation to achieve knowledge transfer and interaction between the basic research and the industrial communities.

2.1 Industry/University Cooperative Research Centers.

To transfer technology, to capitalize on the broad spectrum of research activity in the research university community, there have been "couplings" of industry directly with a university in those disciplines of mutual interest. This led to the NSF program for Industry/University Cooperative Research Centers, a program aimed at technology transfer through the use of research consortia. Goals of the program are:

- o develop industry, state, and other support for industry/university interaction on industrially relevant science and engineering research topics;
- o promote university research to provide a knowledge base for industrial and technological advancement while training students; and
- o promote research centers which become self-sustaining within a five year period, using industry, state and other funding sources.

One of the most important factors in judging which projects are appropriate for support is the likelihood of "success," i.e. that successful research would have implications for technological advances. This enhances the potential for industrial support. Centers provide several mechanisms for cost sharing by industry, insuring that the research is fundamental and technologically relevant. The nature of cooperative research is complex and requires agreement on many issues, both technological and administrative.[6]

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[5] Op. Cit 1.

Success Example. The Center for Ceramics Research, sponsored by the National Science Foundation and the New Jersey Commission on Science and Technology at Rutgers University is a successful prototype. Twenty-three industrial firms participate; each contributes $35,000 annually. Noteworthy is the role of the State of New Jersey in the support of this and four other research centers. State government recognized the opportunity and potential of the NSF concept of Industry/University Cooperative Centers, not just for technology transfer, but for regional industrial development. New Jersey initiated a bond issue for $90 million for this kind of industrial development program and vested authority for administration of the program in a New Jersey Commission for Science and Technology. Now there are five centers in the state, each addressing different technologies. As for the industrial firms participating in the center at Rutgers, their contributions are matched by the Commission for operation, with additional funding available for capital improvements. The Rutgers center is now part of an experimental International Industry/University/Government Research Initiative which is funding a research linkage with center activities in Sweden, broadening the knowledge base and technology transfer.

Indicators of Success. The Industry/University Cooperative Research Centers program has been successful. In 1988 there were 40 operational centers, receiving $20 million in industrial support, $17 million in state support, and $3 million in Federal support. The program has the participation of over 300 industrial firms.

2.2 Engineering Research Centers.

In 1985 the Foundation initiated a program of cross-disciplinary Engineering Research Centers to focus on research, education, and industrial collaboration in areas critical to industrial competitiveness. In 1988 there were eighteen centers. Some examples of the research areas are manufacturing, materials processing, optoelectronics, biotechnology and ocean engineering. About 300 firms are involved with these centers providing funding, equipment, and materials. In line with the "people to people" requirement for technology transfer, the firms are providing engineers to work for extended periods at the centers. In all cases, industry benefits directly from the output of the engineering centers through direct involvement, as illustrated by the Engineering Research Center at Purdue University.

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[6] "Higher Education in Partnership with Industry," D. R. Powers, M.F. Powers, F. Betz, C.B. Aslanian, Jossey-Bass Publishers, San Francisco, 1988.

Illustration: The Engineering Research Center at Purdue University is for "Intelligent Manufacturing Systems," something more than the prevalent emphasis on computer integration and flexibility. It goes beyond the manufacturing practices, where changes in the manufacture of individual parts are effected through changes in software commands. The Purdue Center deals with the next evolutionary step where a larger manufacturing system can respond promptly to changes in design, market, or functional requirements. The key element is responsiveness in the manufacturing process to input or output demands. The Purdue center has seven industrial "partners," each of whom contributes $200,000 annually to the Center. These firms, active participants in the research process, include Alcoa, Chrysler and Cincinnati Millicron. There are also sixteen affiliate firms; each contributes $25,000 annually, receives reports and attends annual meetings. This illustrates the concept of leverage for limited Federal funds for technology transfer to industry to enhance competitiveness.

2.3 Computer Centers.

Another major university/industry NSF research initiative focuses on supercomputing. The Foundation has established five National Supercomputer Centers. These are the:

- San Diego Supercomputer Center
  San Diego, California

- John von Neumann National Supercomputing Center
  Princeton, New Jersey

- Cornell National Supercomputing Facility
  Ithaca, New York

- Pittsburgh Supercomputing Center
  Pittsburgh, Pennsylvania

- National Center for Supercomputing Applications
  University of Illinois
  Champaign, Illinois

These facilities are available to academic, government, individual, and industrial researchers. Allocation of use is generally made on the basis of peer review of the proposed project.

These (and other) advanced computing and networking capabilities permit massive calculations and the simulation of physical phenomena, thus adding another dimension to theoretical and experimental research in the study of complex problems. As with other centers, there is significant industrial participation, usually cash grants for research, equipment donations, or industry researchers who collaborate with researchers in the National Supercomputer Centers. Major computer firms sponsor about $9 million in research in the centers; Cray alone sponsors $2.25 million annually. Other major contributors include Kodak, Amoco, Monsanto, FMC, and Eli Lilly. IBM has, for example, donated a $22 million computer system to the center at Cornell. Additional hardware and software donations and discounts to these centers exceed $20 million in value. Research by industry collaborators has reached the level of about ten percent of the total research efforts of the centers.

Examples. Technological areas which benefit from the application of this type of computational research and simulation are as varied as materials development, communications, and combustion. Examples with commercial applications illustrate the role of these supercomputer centers in technology transfer. Combustion in engines combines the problems of fluid flow with chemical reaction kinetics, a problem which can be "solved" on large computers. The result can be a "visualization" of what happens in the cylinder of an internal combustion engine. This type of research is a prerequisite for improvements in engine design which in turn can result in reduced pollution and improved fuel efficiency.

Computer simulations of bodies moving through air or water furnish insight into the problems of "streamlining." Similar work in aerodynamics has led to devices for truck drag reduction. These two examples, which require supercomputers, coupled with the high level of industrial participation in terms of equipment, sponsorship and research use, indicate how these centers facilitate the flow of research results from the universities to industry.

2.4 Science and Technology Centers.

In response to the President's science and technology centers initiative[7], the Foundation established a new Science and Technology Centers (STC) program. It reflects the reality that an increasing number of important research activities cannot be addressed by scientists working alone. These activities require large investments in facilities and equipment, and researchers with diverse disciplinary backgrounds and expertise. Further, this program recognizes the need to transfer knowledge from discovery to application. The new centers will be based in academic institutions; they will involve scientists from industry and Federal laboratories, in addition to students and academic staff. This approach is designed to accelerate diffusion and application of research findings to benefit all sectors of our society. The goal is to help maintain U.S. preeminence in science and technology and to provide an adequate pool of scientists and engineers with the experience to meet the changing needs of our society, and to meet the challenges of international economic competition.

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[7] State of the Union Message, January 27, 1987; Executive Order No. 12591. April 1987.

Strong Response. The response of the academic community to the STC initiative has been greater than anticipated. Of the 323 proposals submitted, 70 percent involve significant industry participation, a result which augurs well for technology transfer. The Foundation recently announced its support for eleven centers with total funding of $24.7 million in FY 1989.

2.5 The Small Business Innovation Research Program.

The Small Business Innovation Research program was designed and implemented by the Foundation in 1977. It served as the model for the Small Business Innovation Development Act of 1982 and eventually became the national SBIR program. Then as now, it served to stimulate innovation and to facilitate access by small high technology firms to the basic research community. In the decade since its inception, SBIR has complemented the NSF basic research programs by providing a linking mechanism with the marketplace. While many studies may be cited, The Rand Corporation study of 1984 supported by the Foundation[8] showed clearly that the results of basic research do not readily find their way to the marketplace without the use of intermediate mechanisms. Just as with the centers programs, SBIR provides another such mechanism. In addition, NSF's experience demonstrates that businesses which participate in the program also create some of the new research instruments, sensors and materials which in turn are highly useful to the basic research community. Much of this success stems from the deliberate policy to integrate SBIR with the Foundations other research sponsorship, a design feature whereby each NSF research division formulates research topics for the SBIR solicitation.

The SBIR award history shows that the profile of technologies in the funded projects has tracked the National Academy of Sciences five year outlook[9] of 1981 and the OSTP report to the Congress of 1983[10] as to projected national technological needs. Still another measure of relevance to national needs is the emphasis on increased productivity and competitiveness. Of the SBIR research projects funded through 1987, fully 40 percent were related to improved manufacturing processes, productivity, or quality, many of which are already in the marketplace.[11]

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[8] Tora K. Bikson, Barbara E. Quint, Leland L. Johnson, "Scientific and Technical Information Transfer," Rand Corporation, Report to The National Science Foundation, N-2131-NSF, March 1984.

The program's success in technology transfer is best evidenced by the extent of private sector participation. Major industrial firms such as Dow, Eli Lilly, and Martin-Marietta Corporation have supported the development of products or licenses from small firms, either to produce or to use the product or process. Another quantifiable measure of technology transfer is the program's leverage. While the Foundation awarded $20.6 million from 1977 through 1982, the firms participating in these awards have since shown about $400 million of private investments as a result of their SBIR activities as a whole.

Two examples. Successful commercial research products on the market today illustrate the results of SBIR. One is a process for the deposition of silicon carbide used by General Electric for turbine blades. The other is the development of ultra-high-pressure water-jet abrasive machine tools for which cumulative sales reached $22 million in 1987.

2.6 EPSCoR Program.

The development and strengthening of research infrastructure at the state and local level is another aspect of technology transfer. A program that demonstrates just how effective Federal start-up funds can be in creating and developing new science and research infrastructure is the Experimental Program to Stimulate Competitive Research (EPSCoR). Established in 1978 in selected States with NSF support, it is designed to improve the quality of research in science and engineering. EPSCoR provides NSF grants for five years, with the understanding that during this period the research institutions must develop ways to raise their own funds for continuing research. The major thrusts of the program are: to improve regional economic competitiveness by strengthening disciplinary research, to improve research facilities, and to stimulate linkages between universities, industry, and government. The program presently includes institutions in twelve states and Puerto Rico, with each state sharing in the cost.

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[9] "Five Year Outlook on Science and Technology-1981," National Research Council, National Academy of Sciences, Washington, D.C., 1981.

[10] "Annual Science and Technology Report to the Congress," Office of Science and Technology Policy, Washington, D.C., 1983.

[11] cf. Letter from Director, NSF to U.S. General Accounting Office, April 11, 1988, enclosing report "National Science Foundation, Small Business Innovation Research One Decade Later." Report is intended for inclusion in GAO governmentwide evaluation of SBIR.

2.7 International Programs.

The Foundation's International Programs have many elements which relate to technology transfer, especially the transfer of information and researchers. The goal is to know the strengths and weaknesses of the world's research community, in order to help the United States formulate better its own programs and goals. In addition to staff at NSF in Washington, D.C., who administer many bilateral and multilateral science agreements, the Foundation maintains an office in Paris as an entry point to Western Europe, and an office in Tokyo to help carry out the cooperative agreements with Japan.

The Foundation selectively translates Japanese-language reports on research advances. Because many more Japanese come to America than Americans go to Japan, the Foundation is trying to narrow the gap by facilitating the cooperative work of Americans in Japanese research laboratories. NSF also has sought to overcome the language barrier through the development of a short course in technical Japanese. While these are small steps on the international scale, the Foundation recognizes the need to improve technology transfer at the international level.

2.8 Educational Programs.

The Foundation maintains two educational programs with a significant technology transfer component. The first of these is the "Presidential Young Investigator Award." The objective of these awards is to stimulate the retention of outstanding young researchers in universities. It matches institutional and industrial research support to get these researchers started on an academic career. Industry support is matched up to $37,000 by the Foundation, after a base grant of $25,000. Industry, by its support, can get first access to the researcher's results.

The second program, "Private Sector Partnerships," is designed to stimulate and support the involvement of individuals and organizations from the private sector in joint activities with educators and educational organizations to improve science, mathematics, and technology education. The Foundation funds partnership programs for using technical inputs from the industrial world to improve the teaching of the technical and mathematical subjects. This program gets the private sector to share its expertise with educators to improve education.

2.9 Information Distribution and Data Archiving.

Technology transfer is a process which depends heavily on the dissemination of information, either through people directly, or by means of other media. In this activity, it is carried out largely by various disciplinary journals. However, in those research areas which are most active, for example high temperature superconductivity, knowledge or reports of discovery is so "hot," so much in demand by potential industrial users and researchers, that it travels outside the loop of formal publication. NSF encourages and supports attendance at meetings and symposia as an important part in the real time information transfer process. Of equal importance is not just the technical data, but also information on what laboratories are doing, planning, and budgeting.

Insight, a publication of the NSF Division of International Programs, fulfills this need, primarily at the international scientific level. This new periodical also serves to disseminate a broad range of scientific news to the domestic research community. The countries covered range from the European Community to new participants in international technological development such as Brazil and Korea. The objective is to cover a spectrum from policy issues to specific items of scientific research interest. In addition to **Insight**, the Division of International Programs maintains a computer bulletin board on international scientific developments.

STRIDE. This program, Science and Technology Reporting and Information Dissemination Enhancement (STRIDE), is part of an effort to developt a mechanism for the efficient dissemination of science and technology information obtained abroad to users in the public and private sector. The current Foundation activity is in conjunction with Departments of State and Commerce (NTIS). The Foundation has begun producing a desktop-published monthly publication distributed gratis, containing NSF international staff-generated reports.

Data Archiving. Another innovation in information transfer was started by the NSF Division of Social and Economic Science (SES), a policy of data archiving to advance the social sciences by encouraging data sharing among researchers. It requires researchers who enjoy NSF/SES support to commit themselves to placing their documented data sets in a data archive or library within one year after the expiration of the award. In most cases these data sets will be archived by the Inter-University Consortium for Political and Social Research (ICPSR) at the University of Michigan.

NSFNET. Internet, of which NSFnet is the backbone, includes industrial as well as university users. NSFnet, with its transmission rate of 1.5 million bits per second, was conceived as a linkage for the supercomputer centers. Today, it serves a much broader purpose, namely as a high-speed information transfer mechanism which can link the university and the industrial research communities.

3.0 INSTITUTIONAL VIEWS OF NSF'S TECHNOLOGY TRANSFER ROLE

In preparing this response, the Foundation contacted institutions concerned with technology transfer and the application of new technological developments in our society. The interests of these institutions ranged from the academic to the industrial; a complete listing is in Appendix A to this report. While the views were diverse, all of the institutional representatives contacted expressed the belief that the Foundation had taken positive steps to provide for "knowledge transfer" and that some of the programs, like the Engineering Research Centers, provided additional person-to-person technology transfer mechanisms. In definitional terms, each of these institutional representatives had a different view of technology transfer and of the Foundation's role in it.

3.1 Technology Transfer Society.

One of the most-wide ranging of these discussions was with the "Task Force on National Technology Transfer Policy" of the Technology Transfer Society. This group emphasized that the National Science Foundation maintains a vast network of researchers and has access to a large store of research output. It urged the Foundation to initiate a program to make industry aware of NSF research activities and to form a stronger connection between basic research and industry. This would enable industry to judge the relevance or value to their needs. In addition, this group said that the Foundation should conduct research on the technology transfer process itself, to refine the transfer mechanisms and thus to get more "bang" for the research buck. This research would focus on the "science of converting technology for application" and on training in the management of innovation. Another of their suggestions called on NSF to require the grantee to publish "a tutorial on the industrial potential" of the research, something similar to some of the publications of the Agricultural Extension Service. In summary, the Technology Transfer Society's Task Force believes that the Foundation should have an active program beyond its existing activities.

3.2 Industrial Representatives.

Contacts with the institutions representing specific industries, like the Electric Power Research Institute (EPRI) and the

American Electronics Association (AEA), yielded a somewhat different perspective of the Foundation's role in technology transfer. EPRI has a memorandum of understanding with the Foundation which provides for information flow on research activities of interest to electric utilities. AEA is also interested in obtaining more information for its member firms on research which pertains to electronics and materials.

All of these explorations with institutional representatives resulted in many suggestions for the Foundation on how to expand and improve its technology transfer activities. Some of these will be discussed in the next section.

4.0 NEW POTENTIAL TECHNOLOGY TRANSFER INITIATIVES

The technology transfer activities of the Foundation outlined in Section 2 of this report will continue to grow and improve. In the case of the new Science and Technology Centers their interaction with industry will increase, as will the knowledge transfer, as more of these centers are funded. Activities in the Engineering Research Centers and the Industry/University Cooperative Centers already have had positive impact in technology transfer and this will continue to grow. New activities will be considered in the context of the Foundation's role and budget restraint, always keeping in mind that NSF is the only Federal agency with a primary mission in basic research, as juxtaposed to other agencies which have research goals more in line with their overall mission.

The discussions with institutional representatives and groups concerned with technology transfer yielded many valuable suggestions. With regard to these, consideration was given to the requirement to restrain budget growth. Many suggestions emphasized the "person-to-person contact" in new technology transfer activities at the Foundation. Accordingly, this report reflects the importance of "people" as part of the process of knowledge transfer, i.e. the highly trained researchers and industrial representatives who are part of an information transfer process; if they are not, they should be encouraged and helped to participate. Similarly, the potential budget impact of each proposed activity calls for a range of options which follow.[12]

4.1. Knowledge Transfer.

The least costly initiatives, and among the most effective, relate to the improved flow of knowledge and personal contact among university and industrial researchers. This transfer process, which is included in the programs described earlier, can range widely in complexity. Because the Foundation's programs described in Section 2 are in place and will be expanded, there will be a consequent enhancement of knowledge transfer. With the advent of more "centers," there will be greater industrial collaboration and people interaction. These centers inform the academic research process of the research goals of industry, enhancing the emergence of new products. The transfer of knowledge inherent in the research process, and the publication of results, stimulates industrial participation in the university research process and the transfer of knowledge. Further, the prototype **STRIDE** project which the Foundation is starting this year will bring international technical data to users, including industry, via a desktop monthly newsletter.

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[12] Options have letters to facilitate identification and referral, not to indicate priority.

An additional facet of the Foundation's knowledge transfer activity is the Foundation's senior management participation in more interagency advisory panels with industrial participation. Some recent examples of these panels are cited in the Appendix. National priorities dictate close university cooperation with industry in such areas as superconductivity, semiconductors, and advanced television technology.

4.2 Program Options.

Option A: Visiting Professorships to Industry. One of the often cited mechanisms for technology transfer relys on the widely-supported view that "people" are the real transfer agents. This could be used to justify a program of "visiting professorships" with industry sharing the costs. A principal investigator, upon completing a research grant which appears to have technology transfer potential, might submit a proposal for a technology transfer grant; up to one half of his or her salary would stem from the grant, and the remainder from the industrial firm seeking to exploit the newly discovered knowledge. Approximate budgetary impact for fifty such grants per year would be about $2.5 million.

Option B: Campus-Based Research. The program outlined under Section 114 of the National Science Foundation Authorization Act of 1988, the College and University Innovation Research (CUIR) program, is intended as a technology transfer program from universities, large and small, to small business firms. This program will be explored in a separate report to the Congress.[13]

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[13] Report, due March 1, 1989, from Director of NSF to House and Senate Committees, as required under Sec. 114 of Public Law 100-570; 102 Stat 2870.

Option C: Research on Transfer Process. A program of research on the techniques of technology transfer might offer be a meaningful contribution to American competitiveness. The annual cost is estimated to be approximately $1 million but would be highly consonant with NSF's mission and yield potentially practical results.

4.3 Active Existing Transfer Mechanisms.

The Foundation, as this report explains especially in Section 2, now has in place many mechanisms for technology transfer. Results to date indicate that knowledge transfer in these programs is particularly active and that significant industry participation and awareness have been achieved. More industrial participation in these activities is anticipated. Additional emphasis on additional programs will enhance the knowledge transfer process. Adoption of any of the options, described very briefly above, would also certainly increase and accelerate the transfer of research knowledge. The question of whether the program costs can be justified under today's budgetary constraints remains open, especially in the larger context of NSF's overall mission in basic research that need not have a specific application in view.

APPENDIX

Institutional Contacts

American Electronics Association	Richard Iverson
Electric Power Research Institute	Gene Mannella
National Academy of Science University/Industry/Government Roundtable	Donald Phillips
Congressional Research Service Science Policy	Chris Hill
American Association for the Advancement of Science	James Rutherford Al Teich
Technology Transfer Society	Task Force on National Technology Transfer Policy

Interagency/Industry Advisory Committees

National Advisory Committee on Semiconductor R&D

National Commission on Superconductivity

Competiveness Policy Counsel

Committee on Advanced Television (Commerce)

Industry/ Higher Education Counsel

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

nsf
OFFICE OF THE DIRECTOR

March 9, 1989

RECEIVED
MAR 20 1989

Honorable Robert Roe
Chairman
Committee on Science, Space
and Technology
House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

In the report accompanying H.R. 4418, the NSF Authorization Act for Fiscal Years 1989 and 1990, the Committee requested that NSF provide a report indicating the policy of the individual scientific directorates on allowing research grants to cover costs of using regional networks, and to review the success of regional networks in obtaining operations support once NSF withdraws funding. The enclosed report responds to the Committee's information request.

Sincerely,

Erich Bloch
Director

Enclosure: NSF Networking Report to Congress

cc: Honorable Robert Walker

NSF Networking Report to Congress

Introduction

This report responds to the House Science, Space and Technology Committee's report of May 24, 1988 (H.R. 4418), which requests that NSF provide a report indicating the policy of the individual scientific directorates on allowing research grants to cover costs of using regional networks, and reviewing the success of regional networks in obtaining operations support once NSF withdraws funding.

Policies of the Research Directorates

If a proposal to the NSF contained a line item for networking charges, it would be treated the same as any requested direct cost in a proposal and evaluated in the context of the program to which it was submitted. This treatment is identical to that afforded proposed equipment or computing costs.

Practices among campuses are by no means uniform; some charge for connecting computers/workstations to the campus network, but many do not. When charges are made, those for the campus network itself and those to defray levies from the regional (or, "mid-level") network connecting the campus to the NSFNET Backbone are not disaggregated.

Funding of Mid-level Networks

NSF does not have sufficient information to estimate the success of mid-level networks in surviving without direct NSF support. The program is now barely three years old, and the startup awards will soon terminate. Two mid-level networks have nearly completed their initial grants; it is clear that neither is fully self-sufficient and that both will require an additional round of funding. As other startup awards run out, the investigators' final reports and their requests for continued funding will allow NSF to assess their success in obtaining other funding.

Continued funding for mid-level networks will include:

- assisting the startup of new mid-level networks,
- supporting new institutional connections to existing mid-level networks, and
- funding new network-based services.

Support of mid-level networks will continue to advance network capability commensurate with scheduled improvements in the NSFNET Backbone network, and to continue efforts to introduce at least basic networking services to under-served institutions and communities.

NSF policy is to reduce the level of funding over time.

○